W. B. No. 848

U. S. DEPARTMENT OF AGRICULTURE
WEATHER BUREAU

MONTHLY WEATHER REVIEW

VOLUME 52, No. 9

SEPTEMBER, 1924

WASHINGTON
GOVERNMENT PRINTING OFFICE
1924

SEPTEMBER, 1924

CONTENTS

WEATHER OF THE MONTH

† In marine separate.

CHARTS

CORRECTION

REVIEW, June, 1924:

Page 308, in the second column the equation, $\frac{p_1-p}{1-p_1}$, should be $\frac{p_1-p}{1-p}$

MONTHLY WEATHER REVIEW

ALFRED J. HENRY, Editor

Vol. 52, No. 9
W. B. No. 848.

SEPTEMBER, 1924

CLOSED NOVEMBER 3, 1924
ISSUED DECEMBER, 1924

A SYSTEMATICALLY VARYING PERIOD WITH AN AVERAGE LENGTH OF 28 MONTHS IN WEATHER AND SOLAR PHENOMENA [1]

By H. W. CLOUGH

[Weather Bureau, Washington, completed September, 1924]

SYNOPSIS

During the last 25 years a number of writers have called attention to a short cycle in weather elements and have given estimates of its mean length varying from 2.5 to 3.5 years. The diversity in these estimates is due in part to the practice of some investigators of using data with a time interval of 12 months, which leads to high values of the intervals; others employed consecutive 12-month means and derived values of 2.5 to 3.0 years.

In the present paper various statistical criteria and methods are employed to show the extent to which a given succession of meteorological data, such as yearly means of temperature, differs from a purely fortuitous sequence of similar data. In high latitudes the mean interval between two consecutive maxima or minima is less than 3.0 years, which is the mean interval for a perfectly fortuitous sequence. This and other criteria indicate a systematic and persistent tendency to a recurrence of similar phases which differs from that due to chance alone. and this period of recurrence is approximately 2.0 to 2.5 years.

Two methods of investigation, the empirical and the analytical, are discussed and contrasted. The empirical method is illustrated by Wolfer's determination of the epochs of maxima and minima of the solar spots, by Brückner's determination of the epochs of the 35-year cycle, and by Wallén's investigation of the 2.5-year cycle in temperature, rainfall, and lake levels in Sweden.

It is maintained that analytical methods applied to meteorological data, illustrated by Brunt's periodogram analysis of Greenwich temperatures and Beveridge's periodogram of wheat prices in Europe for 300 years, have led to negative results in that no stable periodicity of uniform length has been certainly shown to exist.

In the present investigation two 12-month means per year have been employed, one centered on January 1 and the other on July 1. The adequacy of data in this form for disclosing satisfactorily a cycle of 2.0 to 2.5 years in length is shown by both empirical and analytical methods.

Contemporaneous curves showing meteorological conditions for a number of stations have been drawn for the regions studied, viz. northern Europe and northern United States.

By careful scrutiny and comparison of these curves the epochs of maxima and minima of the short cycle have been determined for pressure and temperature in Europe since 1740 and for temperature in the United States since 1780. Similar phases of pressure over southwestern Europe and of temperature over northern Europe and the northern United States are nearly coincident; the deviations from coincidence are shown to correspond to the accidental errors of observation. Epochs of maxima and minima have also been derived for the pressure in Greenland, which are in general opposite to those in southwestern Europe. The epochs of pressure and temperature for Portland, Oreg., are shown to differ markedly in phase from those for stations in the upper Mississippi Valley. The epochs of maximum and minimum storm velocity in the United States and of maximum and minimum interdiurnal variability of pressure at St. Louis have been derived and it is found that when the temperature over the northern boundary of the United States is low, storm areas move rapidly and the day-to-day fluctuations in pressure and temperature at St. Louis are large. Variations in temperature at New Orleans occur later than at St. Paul, the average difference in the epochs of the short cycle being about four months.

The variations of rainfall show the short cycle with less regularity than those of pressure and temperature, in conformity with the more nearly fortuitous character of this element. In general the epochs of maximum rainfall over northern Europe occur near the epochs of minimum pressure over southern Europe.

It is found that the period under discussion has a mean length of about 28 months, subject to systematic variations in length attributed to the 11-year sunspot period, the 35-year Brückner variation, and to a long secular change, perhaps indicative of a 300-year cycle. The latter is indicated by the general increase in length from about 2.0 years at the middle of the eighteenth century to about 2.5 years at the present time. The 35-year cycle is suggested by a shortening of the period at or near the wet epochs, and a corresponding lengthening at the dry epochs of the Brückner cycle. The 11-year variation seems to be shown by a secondary decrease in the length a few years after the epochs of maxima of sun spots.

A 28-month periodicity is shown to exist in the variations of the mean latitude of sun spots, which shifts systematically from one hemisphere to the other over a range of about 10°. The 11-year and the 35-year variations are shown also to exist in the length of this solar period.

A fairly large correlation exists between the latitude of spots, (regarding north latitude as positive and south latitude as negative), and the temperature at St. Paul one year later, the coefficient being −.56.

Wolfer's smoothed sun spot relative numbers since 1750, with the 11-year variation eliminated, disclose secondary maxima with a tendency to recurrence every 2.3 years, as an average. The 11 and 35 year, as well as the long secular variations are evident in the recurrence of these maxima.

A new graphical scheme is described which facilitates the accurate evaluation of the mean length of the period at any time.

OUTLINE OF TOPICS

[1] The substance of this paper was published in Mo. WEATHER REV., January, 1924, 52:38. The writer desires to express his appreciation of the suggestions and criticisms offered by Prof. C. F. Marvin during the final revision.

I. EARLIER INVESTIGATIONS OF A PERIOD ABOUT THREE YEARS IN LENGTH

The existence of a period in weather phenomena, variously estimated at 2.5 to 3.5 years in length, has been affirmed by a number of students of weather variations during the past 25 years. A very comprehensive summary of such investigations, with bibliography, is contained in the paper of Helland-Hansen and Nansen,[2] and a careful study of this paper should convince an impartial reader that there is something here deserving further investigation.

Probably the first to call attention to this short period was Bigelow,[3] in 1898. He published annual values for 15 years of pressure and temperature for stations in the northwestern United States, together with average velocities of low-pressure areas and cold waves in latitude and longitude, with a plot of the data. He states: "Indeed the occurrence of four subordinate crests in the 11-year period suggests strongly that a 2¾-year period is superimposed upon the long sweep of the periodic curve. Apparently this is more at the basis of the seasonal variations in the United States than anything else, so that in long-range forecasting this period must be very carefully considered." In 1902 [4] and 1903 he published curves of pressure and temperature variations over the entire globe and pointed out that a period of about 3 years is shown by the curves.

The Lockyers [5] published curves of pressure and rainfall variations in India; also curves of solar phenomena, and stated that a short period of about 3.5 years was shown by them. In 1903 they extended the investigation to cover the entire globe and confirmed the earlier results.

Braak [6] in 1910 found a 3.5-year period in the meteorological elements at Batavia. In later years he referred to this as a 3-year period. Variations in temperature occur a few months later than corresponding variations in pressure.

Arctowski [7] has published several papers with curves of consecutive 12-month means relating to this short period, which he regarded as 2¾ years in length.

Wallén since 1910 has discussed in numerous papers a short-period variation in the temperature and rainfall of Sweden and the levels of the Swedish lakes Malar and Wener. He finds a period of about 2.5 years. His studies will be analyzed with some fullness in Section IV.

Helland-Hansen and Nansen in their paper (loc. cit.) published curves of monthly means and consecutive 12-month means of various meteorological elements at Batavia, and concluded that a period of 32 to 33 months is indicated by the curves.

Diversity in estimates of length of period and reasons therefor.—It is obvious that there is considerable diversity of opinion regarding the length of the short cycle. Estimates range from 2.5 to 3.5 years. This is wholly accounted for by the fact that those who incline to the longer interval have employed the calendar year mean, which in the case of a 2.5-year period is entirely too large a unit, and the fluctuations of short length and small amplitude are thereby obscured, resulting in a mean length somewhat too large. Bigelow and the Lockyers used yearly means. Others, as Arctowski, Wallén, and Helland-Hansen and Nansen, employed consecutive 12-month means and determined the length of the period to be 2½ to 2¾ years.

II. STATISTICAL EVIDENCE IN FAVOR OF A 2 TO 2½ YEAR PERIOD

Statistical criteria applied to meteorological data.—The writer,[8] in a statistical analysis of meteorological data, has given evidence showing a predominance of the 3-year interval in any series of annual means for most regions of the globe. However, in applying a criterion based on the relative number of changes of sign in a series of yearly departures such as Mielke's temperature departures for 25 districts over the entire globe, there were disclosed wide variations in different regions. The number of changes of sign is 50 per cent of the total number of values for a wholly fortuitous sequence.[9] Actually there were 12 districts with percentages below 50 per cent and 11 districts with 50 per cent or above. The districts below 50 per cent are in the Southern Hemisphere and the lower latitudes of the Northern Hemisphere, including most of the United States. The districts above 50 per cent include northern Europe and Russia. Scandinavia shows an extreme of 60 per cent. A quotation from the paper follows (p. 129):

> The excessively high values in northern Europe and northwest Russia illustrate the extreme variability of weather in high latitudes. It is obvious that a marked deviation either above or below 50 per cent is indicative of a systematic tendency in the variations. These results are interesting as showing how different are the characteristics of meteorological variations in different latitudes and how unsafe it is to draw general conclusions from investigations covering a restricted area.

A value around 50 per cent indicates that the data are nearly fortuitous in their sequence and that the frequency of the 2-year, 3-year, and 4-year intervals is nearly that of unrelated numbers. A value greater than 50 per cent indicates an abnormal excess of the 2-year interval, and a value less than 50 per cent indicates an excess of the 4-year interval.

To illustrate the excessive predominance of the 2-year interval in high latitudes, the yearly mean temperatures at Stockholm from 1757 to 1918 were examined with the following result: The frequency of the 2-year, 3-year, 4-year, etc., intervals expressed as a percentage of the whole number of intervals between successive maxima or minima, are shown in the table below. The bottom row gives the percentage for fortuitous numbers, as derived from Besson's [10] formula.

Interval in years	2	3	4	5	6	7	8
Yearly temperatures, per cent	48	27	21	3	0	0	1
Fortuitous numbers, per cent	40	33	17	7	2	1	0

The excess of the 2-year interval is clearly indicated.

[2] Temperature Variations in the North Atlantic Ocean and in the Atmosphere. Smith. Misc. Coll., Vol. 70, No. 4, 1920.
[3] Weather Bureau Bulletin No. 21, Abstract of a Report on Solar and Terrestrial Magnetism, 1898.
[4] Bigelow, F. H., A Contribution to Cosmical Meteorology. Mo. WEATHER REV. **30**: 347. 1902.
[5] Lockyer, J. N., and W. J. S., "On some phenomena which suggest a short period of solar and meteorological changes." Proc. Roy. Soc., **70**: 500, 1902.
[6] Braak, C., "Periodische Schwankungen." Met. Zeit. **27**: 121, 1910. See also "Atmospheric variations of short and long duration in the Malay Archipelago and neighboring regions, and the possibility to forecast them." Knk. Mag. Met. Obs.o te Batav. Verh. No. 5. 1919.
[7] Arctowski, Henryk, "The solar constant and the variation of atmospheric temperature at Arequipa and some other stations." Bull. Am. Geog. Soc., vol. **44**: 598, 1912.

[8] Clough, H. W., "A statistical comparison of meteorological data with data of random occurrence." Mo. WEATHER REVIEW, **49**: 128, 1921.
[9] Clough, loc. cit., p. 125.
[10] Besson, Louis, "On the comparison of meteorological data with results of chance." (Translation by E. W. Woolard.) Mo. WEATHER REVIEW, **48**: 89, 1920.

The number of maximum or minimum values of a long sequence of fortuitous numbers is one-third the total number of values, so that the average interval between like phases is the interval between three numbers. In the case of the yearly numbers representing the temperature for Stockholm during the period from 1757 to 1794 the mean interval is 2.47 years, while from 1757 to 1826 it is 2.65 years and from 1838 to 1918, 2.82 years. For Copenhagen, 1798 to 1921, the average is 2.73 years. For Halmsted, 1859 to 1918, the average is 2.56 years. For Christiania, 1874 to 1922, the average is 2.61 years. These values, markedly below the theoretical 3.0 for unrelated numbers, are obvious evidence that the variations of the data are systematic, that is, not fortuitous, and indicate a periodicity around 2½ years, or less.

The tendency of the 3-year interval to predominate in lower latitudes is shown by the yearly temperatures at Berlin and Turin. At the former, from 1719 to 1907, the mean interval is almost exactly 3.0 years, while in still lower latitudes, at Turin, the mean interval is 3.5 years. This is due to the systematic decrease in amplitude with decrease in latitude, resulting in the disappearance of fluctuations of small amplitude, when yearly means only are employed.

Another criterion is furnished by the number of times when maxima and minima are separated by an interval of only 1 year, expressed as a percentage of the cases of record. A number of long temperature records in northern Europe were examined and percentages in excess of that for unrelated numbers, 41 per cent (cf. Besson, loc. cit.), was found, as follows: Stockholm, 1757–1826, 53 per cent, 1849–1918, 52 per cent; Halmsted, 1859–1918, 60 per cent; Copenhagen, 1798–1850, 48 per cent; 1850–1921, 59 per cent. These values further illustrate a tendency to an abnormal excess of cases when one extreme followed the opposite extreme with an interval of only 1 year.

In low latitudes, e. g., Turin, the percentage of single rises and falls, 25 per cent, is less than the theoretical percentage for unrelated numbers.

The number of single rises and falls during successive 5-year periods from 1755 was determined for four regions in Europe, the data being based on Köppen's and Mielke's regional departures of temperature. The regions are (1) Great Britain, (2) northern Germany and Holland, (3) west-central Europe, and (4) Austria. The number per lustrum for the four regions named are given in the following table, together with their average. There are well-defined maxima in the lustra 1781–1785, 1811–1815, 1841–1845, 1881–1885, and there are also indications of a maximum around 1910 or 1915 shown by data at Stockholm and Copenhagen. These epochs of maximum single rises and falls per lustrum are nearly synchronous with the Brückner epochs of maximum precipitation 1775, 1815, 1846–1850, 1880, 1915. There is thus shown statistically a tendency for the occurrence of more rapid oscillations of temperature approximating a 2-year period, during the wet portions of the Brückner period. This is consistent with results derived in Section V of this paper.

Table of number of single rises and falls per 5 years:

Lustrum ending	1760	1765	1770	1775	1780	1785	1790	1795	1800	1805	1810	1815	1820	1825	1830
Region 1	---	---	---	1	2	5	2	3	1	2	4	4	1	1	3
" 2	3	3	2	2	1	4	0	1	1	1	3	5	2	3	2
" 3	1	1	0	1	2	4	0	1	1	1	3	5	2	2	2
" 4	---	---	---	2	1	4	1	1	1	1	2	3	1	3	1
Average	2.0	2.0	1.0	1.5	1.5	[1]4.2	0.8	1.5	1.0	1.2	3.0	[1]4.2	1.5	2.2	2.0

[1] Maximum values nearly coincident with wet epochs of Brückner period.

Lustrum ending	1835	1840	1845	1850	1855	1860	1865	1870	1875	1880	1885	1890	1895	1900	1905	1910
Region 1	0	2	3	3	3	3	2	1	1	2	5	2	1	0	0	4
" 2	1	1	5	2	2	3	1	2	1	1	5	2	0	5	2	4
" 3	1	2	4	3	3	3	1	2	1	1	5	5	0	1	2	2
" 4	1	3	5	3	0	2	2	2	1	1	4	0	4	2	1	1
Average	0.8	2.0	[1]4.2	2.8	2.0	2.7	1.5	1.8	1.0	1.2	[1]4.8	2.3	1.2	2.0	1.2	[1]3.0

[1] Maximum values nearly coincident with wet epochs of Brückner period.

A statistical analysis of the composite European temperature departures referred to in section V, from 1730 to 1920 by 50-year periods, (last period 40 years) showing the frequency of the various intervals between consecutive maxima or consecutive minima, expressed as a percentage of the whole number of such intervals, is given in the table below. The data being 6-month means smoothed by the formula (a+b)÷2, are compared with like results from unrelated numbers smoothed by the same formula. The frequencies for unrelated numbers were determined empirically by the writer.

Interval	2	3	4	5	6	7	8	9	10	Sum of frequencies 5 to 10
Unrelated numbers	15	33	22	14	8	5	2	---	---	29
1730–1780	9	36	32	13	9	---	---	---	---	22
1780–1830	2	30	33	9	5	9	9	---	2	34
1830–1880	2	29	32	29	4	4	---	---	---	37
1880–1920	0	36	33	6	17	8	---	---	---	31
Average 1730–1920	4	33	32	14	9	5	2	---	---	30

The significant features are the relatively infrequent occurrence in each of the 50-year periods of the two-interval, and the excess of the four-interval, as compared with the theoretical values for unrelated numbers. Each set of values is based on 100 items, two for each of the 50 years. The approximate mode of the frequency distribution for the average is 3.5, as compared with a mode of about 3.15 for smoothed unrelated numbers.

These results indicate the persistent tendency over a long period of time for meteorological data to show systematic departures from a fortuitous order of succession. The excess of the four-interval, corresponding to a 2-year sequence, points to the existence of a period somewhere near this length of time. The sums of the frequencies for the intervals greater than four show a systematic increase from the early to the later series, while the two-interval shows a corresponding persistent decrease, both of which features are consistent with results deduced in a later section of this paper relative to a secular increase in the length of this period during the last 175 years.

Some persistent biennial recurrences discussed and analyzed.—C. F. Brooks[11] has called attention to sequences of alternately cold and warm winters, or where a winter warmer (or colder) than the preceding winter was followed by a colder (or warmer) winter. Such alternations occurred several times in succession in two or three instances in the nineteenth century, notably 1804–1810, and 1872–1883, and again around 1920. In a discussion of Brooks's paper (p. 73, loc. cit.) I showed that the number of such alternations occurred at three stations with records of 85 to 100 years on an average of 15 per cent in excess of the number required by theory if there

[11] Brooks, C. F., "Sequence of winters in the northeastern United States." Mo. Weather Rev. 49: 71, 1921.

were no relation between the character of successive winters, and furthermore that the particular sequence of 10 to 12 alternations in the seventies and eighties of the last century would occur only once in about 3,000 years, if the occurrence were purely fortuitous. If the remarkable approach to uniformity in amplitude of the series were taken into account, it is probable that a series of 10,000 values would be required to yield such a sequence. It is obvious, therefore, that the existence of such a sequence is strong presumptive evidence that there is a tendency to a cyclical recurrence, at times, in winter temperatures, averaging two years in length.

Reference should here be made to a paper by Clayton [12], in which he discussed a cyclical recurrence of temperature, pressure, and rainfall in the United States, averaging about 25 months, in the late seventies and early eighties of the last century. The regularity of recurrence, however, disappeared in later years.

Douglas [13] notes a prominent 2-year oscillation in tree growth as shown by the rings. He writes:

> In the cross-identification of the trees a constantly recurring feature has been a marked alternation in size of successive rings, giving them the appearance of being arranged in pairs. In the plotted curves this produces a zigzag or seesaw effect. Usually such effect lasts a few years and then disappears, but one example shows unusual persistence—between 750 B. C. and 660 B. C. The even dates show less growth than the odd almost continuously for 60 years, but for the next 30 years the reverse is the case. This is evidently due to a short period of about 2 years in length. It has not been fully studied, but it is prominent in the European groups and in the Vermont group. It frequently shows a duration of a little less than 7 years in one phase with odd dates greater in growth than even dates, and then for the next 7 years reverses its phase. This 14-year cycle is the series of beats the 2-year cycle produces by interfering with the exact annual and biennial effects in the tree. Hence by a simple process its length is found to be in effect frequently 21 or 28 months. Comparison has been made with the rainfall records near the Vermont group and a variable period has been found averaging near the larger value.

This is another instance of a biennial recurrence in much greater frequency than if the climates of successive years were wholly unrelated.

Length of period derived approximately by method of correlation.—The method of correlation affords a ready means of evaluating the degree of relationship shown by two curves. Indirectly it may confirm the existence of a periodic recurrence of values in the data composing a single curve and which may be obvious on simple inspection. For example, if a series of data such as 12-month means at 6-month intervals be correlated with the same data 6, 12, 18, etc., months later, and the process be repeated indefinitely, a recurrent period in the data will be shown by a systematic change in the correlation coefficients from +1.00 to minus values and back to plus values repeatedly as the two curves are by this process in effect shifted so as to bring like phases of the period successively into conjunction or opposition with each other. If the data represent a true periodic function, the coefficients will range between +1.00 and −1.00. A lesser degree of regularity in the recurrence will be shown by lower coefficients. The mean period-length is derived from the average interval between like phases in the series of coefficients. Illustration of the results obtained by this process is shown in the following table, which gives the coefficients for the pressure and temperature variations at St. Paul from 1872 to 1924.

Years	Pressure	Temperature	Years	Pressure	Temperature	Years	Pressure	Temperature
	r	r		r	r		r	r
0.0	+1.00	+1.00	3.0	−0.11	−0.35	6.0	−0.45	−0.11
0.5	+.41	+.36	3.5	−.43	−.46	6.5	−.38	−.22
1.0	−.70	−.67	4.0	−.39	+.19	7.0	−.43	−.34
1.5	−.53	−.47	4.5	+.31	+.35	7.5	+.50	−.00
2.0	+.32	+.38	5.0	+.45	+.25	8.0	−.19	+.44
2.5	+.43	+.40	5.5	+.16	−.00			

The mean length of period to the nearest half year by this method for both pressure and temperature is seen to be 2.5 years. In reality the result by this method probably coincides closely with the mode obtained by a frequency classification of the intervals between the more pronounced maxima and minima. The distribution of phase-intervals for both solar and terrestrial periods appears to be slightly unsymmetrical and the skewness is positive, that is, the arithmetic mean is greater than the mode. Hence the result by the correlation method may be somewhat less than the arithmetic mean.

The method of correlation employed is that of concurrent variations, which gives a numerical expression for the tendency of two related variables to increase or decrease simultaneously. If the variations of each variable be represented by plus or minus signs, there will be n pairs of signs, which may be either like or unlike. Let c denote the number of pairs of signs, which predominate. Then the coefficient of correlation is $r = \pm\sqrt{\frac{(2c-n)}{n}}$. The coefficient is positive or negative, as the pairs with like or unlike signs predominate. The coefficient by this method is theoretically identical, when n is large, with that by the ordinary method when the variations between successive items, instead of departures from the mean, are employed.

Conclusion.—The statistical and other evidence thus far adduced in favor of a period between 2 and 2½ years is cumulative to a degree that is almost conclusive as to its existence. Moreover this evidence is mostly of a direct mathematical character that entirely precludes any personal bias entering into the results.

III. EVIDENCE FOR VARIABILITY IN THE LENGTH OF PERIODS

The question as to the existence of periods of systematically varying length is a fundamental one in this discussion and the evidence for the existence of such features in real periods will now be reviewed.

Variable stars.—The intervals between maximum brilliancy of some long-period variable stars are, it is well known, subject to marked variations in length. This variability is not of an accidental nature due to errors of observation or paucity of data, but must be regarded as systematic.

Statistical evidence for the systematic variability of the sun-spot period.—This period is well known to be of variable length, with an extreme range from 7 to 16 years, during the 310 years from 1610 to 1920. In this period of time we find by actual count that one-third of the intervals between successive maxima or successive minima are less than 10 years or greater than 12 years. I have applied various statistical criteria to Newcomb's [14]

[12] Clayton, H. H., "A lately discovered meteorological cycle." AM. MET'L JOUR., 1: 130, 1884.

[13] Douglas, A. E., "Climatic cycles and tree growth." Carnegie Institution of Washington, Pub. No. 289, p. 106, 1919.

[14] Newcomb, Simon, "On the period of the solar spots." Astro. Jour. 13:1. 1901.

residuals, i. e., the differences between his computed normal epochs and the observed epochs for a period of 300 years. The mean deviation of the residuals of the epochs of maxima is 1.27 years, and of the minima 1.00 years; while the mean variabilities are 1.49 and 1.26 years, respectively. If the sequence of the residuals were of a fortuitous character, the ratio, mean variability divided by the mean deviation, would be 1.41[15] instead of being actually 1.21. The latter ratio being so much less than the theoretical ratio for unrelated numbers indicates the existence of marked systematic characteristics in the residuals.

A further criterion is one based on the relative number of changes of sign in a series of residuals. The percentage of the whole number of such sign changes to the total number of residuals should be 50 for unrelated numbers. The percentage for the sun-spot residuals is 35.

The systematic character of the sun-spot intervals is shown by another criterion based on a comparison of results obtained by means of a smoothing formula. If the successive values, a, the interval from minimum to maximum, and b, the interval from maximum to minimum, be tabulated for the entire period from 1600 to 1900 and smoothed by the formula $\frac{a+2b+c}{4}$, there are obtained 17 well defined maxima and minima for the total 54 phase values. Assuming 8.5 as the average number of maxima or minima, it follows that the average interval between maxima or minima is 6.4 phase values. The corresponding mean interval for unrelated numbers smoothed by this formula is 4.7, a value determined empirically by the writer. The average phase value is 5.56 years or the average of a and b; hence the average interval is $5.56 \times 6.4 = 35.6$ years or the Brückner period, which is thus shown to exist in solar data.

Summarizing the statistical evidence cited above, we find strong evidence of the systematic variability of the length of the sun spot period. Accordingly, those who oppose the claim that the length of the sun spot period *varies systematically* must refute or otherwise adequately interpret the impersonal statistical evidence thereof just cited.

Empirical evidence of periodic variation in length of sun spot period.—In an earlier paper [16] I showed that this systematic variation in the length of the sun spot period was a periodic variation, in the sense that recurrences of long or short periods occur at intervals varying from 25 to 45 or 50 years, with an average interval of about 36 years, and supported this by [the] curves showing similar secular variations in the spot numbers at maxima, and in the ratio $a:b$, or the ratio of the ascent from minimum to maximum to the descent from maximum to minimum. The close synchronism between the variations of these three solar elements is strong evidence as to the reality of the 36-year period. It was further shown that this 36-year secular variation in the length of the 11-year sun spot period which has persisted since 1600, is also well marked in the "probable maxima" of Fritz [17] since 1000 A. D. The latter are based partly on Chinese observations of spots visible to the naked eye, and partly on observations of the aurora in Europe.

Relative accuracy of old and modern sun spot data.—Since the value of the mean deviation of Newcomb's residuals is greater for the epochs of the maximum of spottedness than for the epochs of minimum, we must conclude that the latter recur with greater regularity or that their dates are more definite and more easily fixed. Furthermore, notwithstanding the much greater weight Wolfer has given to later observations of spottedness, the mean deviation of the residuals for the interval 1610 to 1750 is only slightly in excess of that for the interval 1750 to 1900. The proper interpretation to put upon this result is this: The causes which produce the considerable irregularities in the lengths of the periods are mostly systematic and due to some law of nature, whereas actual errors in determinations of the epochs are relatively small and have but a slight effect, so that the old and supposedly inaccurate observations are really quite as trustworthy for purposes of fixing the mean length of the sun spot period and its variations as the more exact and detailed modern data.

This statement applies also to the "probable maxima" of Fritz, the general accuracy of which, notwithstanding the apparent inadequacy of the data upon which they are based, is indicated by the persistency with which recurrences of long or short intervals between maxima, averaging 36 years apart, have appeared throughout the series. The writer has recently completed a statistical analysis of these early sun spot maxima, which in a remarkable manner confirms their general accuracy and their coordination with modern data.

Periodic variations in the length of the Brückner period.—Passing from solar to terrestrial data, it is to be noted that the Brückner period is also a variable period. Brückner fully recognized the variability in its length, as shown by his table of frequencies for various period lengths.[18]

Period lengths.......................years..	20	25	30	35	40	45	50
Frequencies..........................cases..	6	10	12	13	12	8	4

These values yield a mean length of about 35 years, with a probable error of ± 0.7 year. The extremes of 20 and 50 years may be regarded as due chiefly to the phase-shifting influence of shorter periods, but there can be no question that the length of the period has varied systematically between 25 and 45 years.

In the paper referred to above I showed that there is a close synchronism between the solar 36-year period and the Brückner period, the length of which I determined to be about 36 years. Short sun spot intervals, ranging from 7 to 10 years, invariably precede by an average of 10 years Brückner's epochs of cold winters. This close relationship is mutually confirmatory of both Brückner epochs from 1000 A. D. and the sun spot epochs of Wolfer from 1610, as well as the "probable maxima" of Fritz, from 1000 A. D. to 1600 A. D.

It was still further pointed out that the Brückner period and also the 36-year solar period show synchronous secular variations in length, ranging from 25 to 45 years, and evidence was given to show that this periodic recurrence of long and short intervals has occurred about every 300 years.

Variability of the 7-year period.—Another meteorological period of variable length is the period of about 7¼ years, which the writer has extensively investigated. A partial summary of this investigation, containing curves of temperature, pressure, and rainfall for the United States, was published in 1920.[19] The tempera-

[15] Ch. Goutereau, "Sur la variabilité de la température." Annuaire de la Société météorologique de France, 1906, 54; 122.

[16] Clough, H. W., "Synchronous variations in solar and terrestrial phenomena," Astro. Jour. 22: 59, 1905.

[17] Fritz, H., "Die Perioden solarer und terrestrischer Erscheinungen." Viertel. der Nat. Gesell. Zurich, 1893.

[18] Brückner, E., "Klimaschwankungen seit 1700," Geogr. Abhand. Band 4, Heft 277, Vienna, 1890.

[19] Clough, H. W., "An approximate 7-year period in terrestrial weather with solar correlation." MO. WEATHER REV., 48: 593-597, 1920.

ture curves from 1790 show that the intervals between maxima or minima have ranged between 5 and 10 years, and a smoothed plot of these period intervals shows close correlation with a curve of variations in the length of the 11-year sun spot period. Both curves show well marked secular variations with a period of 30 to 35 years, the terrestrial curve following somewhat the solar curve.

Conclusion.—The evidence, therefore, seems to indicate that variations in the periods of the sun and stars may occur, not of a purely accidental type due to uneliminated errors of observation or lack of adequate data, but definitely shown to be of a systematic and even of a periodic nature, and that similar variations occur in terrestrial periods, as the 36-year Brückner period and the 7¼-year period.

It would seem, therefore, in keeping with the evidence thus far adduced, that the attitude of one approaching the study of short-period variations in weather should at least be one of open-mindedness regarding the question of systematic or periodic variations in the length of such periods.

IV. METHODS OF INVESTIGATING PERIODICITIES

Among several important methods which investigators of weather sequences may employ, two will be contrasted and discussed somewhat at length: (1) An empirical method based largely upon careful examination of curves drawn free-hand through plotted data or derived by means of smoothing formulae; (2) a mathematical analysis, illustrated by the various applications of the harmonic analysis, including the Schuster periodogram and a new graphical periodicity tabulation to be described below. These methods are not in any sense exclusive of each other; rather, the second method may be said to be supplementary to the first, with the object of obtaining a possible quantitative evaluation of the results derived thereby.

The following extract from a paper by Bigelow [20] gives an impartial statement as to the relative merits of the two methods:

> The problem is so exceedingly difficult that we may fairly be permitted to employ such means of discussion as are obviously suitable to avoid an inevitable failure in reaching a valuable result. The problems of solar and terrestrial synchronism can be discussed by two general methods—a strictly rigid mathematical method, and a statistical method, combined with an interpretation guided by graphic traces. The former is preferred by some as applying definite principles and allowing no chance for accomodation by a biased judgment; the latter is preferred by many as the only method for a first approximation to a clear understanding of relations too complicated to be unraveled by any mathematical method now in existence. Some criticize the former method as allowing no room for the practical judgment, and others criticise the latter method as allowing too much room for the judgment, especially on the part of those who seek a special result. The truth seems to be that the former method is allowable for the adjustment of the constants and terms of an equation, wherein the physical processes are already approximately understood. The latter method is necessary and allowable in those preliminary researches which seek to discover what the law is rather than in the refinement of it. The first method always leads to zero results in dealing with solar and terrestrial phenomena; the latter offers some hope of success in the present state of the development of the science.
>
> We mean to include under the former method of rigid analysis (1) the usual application of the theory of least squares for the detection of an unknown period; (2) Professor Schuster's "Harmonic analysis and periodogram for the detection of hidden periodicities," Terr. Mag. 1898; (3) the Fourier series and sequence in various forms of the harmonic analysis; (4) Professor Newcomb's "Criterion for fluctuations without any discernible period," Tran. Am. Phil. Soc. vol. XXI, part V, 1908.

[20] Bigelow, F. H., "Studies on the general circulation of the earth's atmosphere." Am. Jour. Sci. 29: 281, 1910.

First method.—As an example of the first method, the determination of the epochs of sun spot maxima and minima may be cited. Schwabe observed the sun for little more than three complete periods and on this basis announced his discovery, which was gradually accepted by astronomers. In this case the range between maxima and minima is so great that a simple inspection of the curves representing the observations is convincing. Later, Wolf and his successor Wolfer compiled all available observations as far back as 1605, and showed the average length to be 11⅛ years, with variations ranging from 7 to 16 years.

However, the long interval from the maximum of 1788 to the maximum of 1805 was regarded by some as a double period with an intermediate primary maximum. Young states (The Sun, p. 149): "Some astronomers contend that there ought to be another maximum included about 1795. Observations about this time are few in number and not very satisfactory." A controversy over this matter lasted many years until Wolf definitely settled the question and showed that magnetic and auroral data are confirmatory of the long period.

Wolf [21] determined empirically the sun spot epochs by means of his smoothed numbers consisting of consecutive 12-month means still further smoothed by taking means of two consecutive 12-month means centered on the first of the contiguous months, giving a result as of the 15th of the first month. Some maxima in spite of the smoothing showed double crests and in such cases the epoch was assigned to a point intermediate between the crests. The method is entirely empirical and another might assign slightly different epochs from an inspection of the curves. The fact that variations in the diurnal range of magnetic declination show high correlation with the sun spot variations, as do also auroral data, may be said to confirm the accuracy of the empirically determined sun spot epochs.

The determination of Brückner period is a further illustration of the first method of investigation. Brückner employed 5-year means as units and deduced from simple inspection of the data, in both tabular and graphic form, the dates of maximum and minimum values of the period which bears his name.

Second method.—When analytical methods which involve the assumption of a uniform period are employed, an obstacle immediately presents itself. The variability in the length of the period rapidly reduces the amplitude derived from a periodicity tabulation of more than a few rows. The amplitude of the sun spot period, for example, is reduced nearly 50 per cent if the yearly values are tabulated by 11-year recurrences from 1750, owing to the varying length of the period. For this and other reasons the many investigations in which the Fourier analysis has been employed have failed to give certain evidence of any period of uniform length in weather data.

A noteworthy example of this method is Brunt's [22] discussion of the monthly residuals of temperature at Greenwich, 1841–1905, which led to negative results. He states:

> The investigation of the continuity of the different periods considered above points to the conclusion that there exists no stable periodicity except the annual one. If this conclusion is justified, it is clear that the periodogram analysis is not in itself sufficient to deal with temperature variations.

[21] Wolfer's revised monthly relative numbers, actual and smoothed, with a discussion of the method employed in deriving the epochs of maxima and minima will be found in Mo. WEATHER REV. 30:171, 1902.

[22] Brunt, D., "A periodogram analysis of the Greenwich temperature records." Quart. Jour. Roy. Meteor. Soc. 45:335, 1919.

Perhaps the most notable example of the periodogram method is afforded by Beveridge's[23] investigation of weather and harvest cycles. He analyzes wheat prices in western Europe based on data for 300 years and finds a number of apparent periods with amplitudes which he regards as sufficiently large to be significant. Efforts to support the reality of these periods by reference to supposed meteorological parallels are not very successful. If the systematic variability in the length of meteorological periods is admitted, this method has limitations upon its use, and results so secured must be interpreted in the light of those limitations, particularly for the shorter periods, where 20 to 30 or more recurrences are involved.

Probably the most noteworthy feature of his periodogram is the relatively large amplitude appearing at 35.5 years. This length of period is approximately that of the Brückner period, and the phases of maximum wheat prices agree closely with Brückner's cold, wet epochs. There being only eight recurrences, a fairly large amplitude survives despite the variation in the length of the period. Beveridge's results may be said to be definitely confirmatory of the reality and importance of the Brückner period.

It is highly probable, therefore, that if there exists any real period of uniform length it would have been discovered by now, since numerous investigators have employed methods of mathematical analysis which would inevitably result in the emergence of such a period if it existed. In view of the further fact that the sequence of values in meteorological data, particularly for temperature, is systematic to a high degree, the inference is that the recurrent features thus indicated are variable to an extent sufficient to limit the usefulness of refined analytical methods and to make difficult and uncertain the interpretation of results so attained.

Discussion of Wallén's[24] methods and results.—The investigations of Wallén will now be given somewhat detailed consideration because they constitute a good example of the use of the empirical method of analysis. He has for a number of years issued annual forecasts of the level of the Swedish lakes Malar and Wener, based upon the short period of 2½ years and an 11-year period. He employed the rainfall record at Upsala from 1740, the temperature at Stockholm from 1757, and the stages of Lake Malar from 1774, to determine the normal periods and amplitudes which he employs in making his forecasts.

The fundamental principle of his method consists of the methodical elimination of the different periods, proceeding from the shortest, or annual, to the longest by the formation of mean values of continuous groups having a number of terms equal to that of the period to be eliminated. Thus the annual period is eliminated by running 12-month means, still further smoothed by consecutive means of 5 terms. The 2½-year period is then eliminated by combining these means into consecutive means of say, 36 terms. The differences between these two series yield the 2½-year period with the annual and secular variations eliminated. These operations do not alter the length or the phase of the period; but the amplitude suffers diminution, for which, however, it is easy to make a correction, as will be shown.

While the present writer fully approves of the method used by Wallén, it seems necessary to digress briefly at this point in order to present and analyze the conclusions reached by him and, if possible, to harmonize his findings concerning the periodicity of about 2½ years with the findings of the present investigation, as set forth below. From the curves obtained by the methods outlined above, Wallén derived empirically, by simple inspection, the epochs of maxima and minima of the 2.5-year period, thereby obtaining a mean of 30 months for Lake Malar, 24 months for the rainfall at Upsala, and 26 months for the temperature at Stockholm. Assuming the amplitude of the annual period for each element as 1.0, he derived a value of 0.94 for the amplitude of the 30-month period in the variations of Lake Malar, and 0.44 for the amplitude of the 30-month period in the rainfall at Upsala. Wallén's phase-intervals for Lake Malar when arranged in a frequency tabulation show a mode at 28 months. The mode for the rainfall phase-intervals is about 23 months, while the temperature at Stockholm yields a mode at 24.5 months.

These differences in Wallén's results for three meteorological elements at practically the same locality are due to the fact that in the rainfall data certain minor maxima and minima occur which do not have a corresponding feature in the variations of the lake level, owing to the storage effect of the lake. The phases of the 30-month variation in the lake level occur normally about 2 months after corresponding phases in the rainfall. Thus Wallén derives a value for the period in the lake levels somewhat greater than that for the rainfall. Owing to the fact that the amplitude of the annual variation in the lake level is but little in excess of that of the 30-month period, while in the case of the rainfall it is more than double, it is reasonable to infer that the variations in the lake level represent more nearly the actual short-period variations, since the annual variation, being relatively much smaller, can be more perfectly eliminated than in the case of rainfall. Furthermore, it is irrational to suppose that elements as closely related as rainfall and lake levels in the same locality should not theoretically have closely corresponding maxima amd minima with precisely the same average length of period. Wallén has also investigated the levels of Lake Wener from 1807. He finds that maxima and minima in this lake occur slightly later than corresponding phases for Lake Malar, and that certain fluctuations in the latter are not clearly obvious in the larger lake, and he accordingly derives a mean period of 33 months for this lake. These differences are due solely to the greater storage capacity of the larger lake, resulting in occasional fusion of two consecutive maxima or minima of the smaller lake. It will be shown below why my epochs for the level of Lake Malar differ in some respects from those of Wallén.

The 12-month smoothing process.—Resuming again the consideration of empirical methods with special reference to the elimination of possible other short-length periods, the primary object of any smoothing process is to eliminate minor variations in order to present more clearly important major variations. The particular formula to be used depends upon the precise object in view.

The objects to be attained by the running 12-month mean are twofold: (1) The elimination of the annual variation. This procedure is, as a rule, effective for this purpose; but in the case of rainfall, at times when the annual variation is not normal, this elimination is not perfectly accomplished and uneliminated effects may cause a slight shifting in the phase of the longer period at such times. Such phase shiftings may, however, be regarded as deviations of an accidental nature and could

[23] Beveridge, Sir William, "Wheat prices and rainfall in western Europe," Jour. Roy. Statis. Soc. 85:412-478, 1922.

[24] Wallén, A., "Fleråriga Variationer hos Vattenståndet i Mälaren, Nederbörden i Upsala och Luft-temperaturen i Stockholm." Meddelanden från Hydrografiska byrån, 4. Stockholm, 1913.

not amount to more than a quarter of a year at the most. (2) Elimination of possible periods of under and slightly over one year in length. According to a formula due to Schreiber,[25] we can determine how much the amplitude of a periodic function is weakened through the formation of running means with a certain number of terms.

Let the function be

$$y = a \sin\left(\frac{180^\circ}{l} + b\right)$$

in which a = the amplitude
l = the length of the period.

If running means of n terms be found, there is obtained the new periodic function

$$\eta = \mu\, a \sin\left(\frac{180^\circ}{l} + b\right)$$

where μ is a factor that expresses how much the amplitude is diminished. μ has the following form:

$$\mu = \frac{\sin n\left(\dfrac{180^\circ}{l}\right)}{n \sin\left(\dfrac{180^\circ}{l}\right)}$$

in which n and l are in the same units.

I have computed the value of this factor μ for various lengths of periods up to 36 months where n=12. The results are shown in the following table, in which l represents the length of the period and μ the percentage of the true amplitude.

l	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	18	20	24	30	36
μ	0	0	0	−13	0	−15	−22	−21	−16	−8	0	+8	+16	+24	+30	+41	+51	+64	+76	+83

It appears that periods commensurate with 12 months, as, 2, 3, 4, and 6 months are entirely eliminated, while incommensurate periods, as 7 to 11 months, appear with reversed phase (shown by the minus sign) and greatly reduced amplitude, amounting to only about one-fifth the original magnitude for the maximum possible effect at 8 or 9 months. One may reasonably infer from this—and a study of numerous curves is confirmatory—that the effect of periods shorter than one year is practically negligible and confined to a slight shifting of phase which may be regarded as of an accidental nature. In actual practice, the further smoothing of the 12-month means by consecutive means of five terms effectually eliminates all possible periods under 1 year.

As to the existence of possible periods longer than 1 year the table shows that the amplitude of periods up to 16 months is reduced to less than one-third of the original amount, while with an additional five-term smoothing the reduction is to 26 per cent or less, so that these may be practically disregarded in the 12-month means. As to the possible existence of periods between 16 and 24 months, the evidence of the curves is emphatically in the negative. The existence of such periods would be shown by the frequent occurrence of minor or supplementary crests or hollows, and such features are relatively infrequent in the temperature and pressure curves.

The practical absence of such supplemental phases in the 12-month means indicates that the amplitude of possible periods between 16 and 24 months is very much smaller than that of the 28-month period and that their only effect would be an apparent shifting of the phase, which may be regarded as of the nature of an accidental deviation. These several accidental deviations of the phase due to abnormal annual variation, and possible short periods should as a rule neutralize each other, and the best possible evidence that they generally do is furnished by a frequency tabulation of the phase intervals of some of the curves examined. There is no *a priori* reason why a 20-month interval, for example, should not appear as the chief mode in such a tabulation, since theoretically it should appear in the curve with 51 per cent of its original amplitude. As a matter of fact the most frequent interval for the variations of Lake Malar, for example with annual and secular variations eliminated, is about 28 months and the distribution is unimodal and nearly symmetrical, showing that the deviations are of an accidental nature.

A curve of running 12-month means exhibits numerous small fluctuations superposed upon the long variation of two or more years and these may be smoothed out, as did Wallén, by forming consecutive means of five terms. By employing only two of the these 12-month means, 6 months apart, nearly the same result is effected, with, however, a corresponding reduction in amplitude, which is shared to an even greater degree by the possible short periods. For a 30-month period the 12-month smoothing effects a reduction in amplitude to 76 per cent, according to the above table giving the values of μ. A selection of two of the 12-month means, 6 months apart, effects a still further reduction, amounting to about 90 per cent. Hence the original amplitude of the period is reduced to 0.76×0.90 or 68 per cent by this process. For a 24-month period the resulting amplitude is about 60 per cent.

Methods employed in the present investigation.—In this investigation I have employed the ordinary calendar-year mean centered on July 1 and the 12-month mean centered on January 1. In deriving the latter mean the two half-yearly means beginning January 1 and July 1 of each year were computed, their mean being checked with the published annual mean, and finally the 12-month mean centered on January 1 was determined by averaging the second half of each year with the first half of the next. The computation of this mean involves only slight labor compared with that of 12-month consecutive means, which is prohibitive when the research involves the amount of data necessary to results of adequate generality. The use of these two means six months apart has given good satisfaction, since the annual period is eliminated in the only manner entirely satisfactory, and the months with large departures are grouped together in the January 1 mean. When it is recognized that two points suffice to completely fix a sine wave of given wave length if the coordinates are given with reference to the axis of the wave, it is clear that irregular wave forms may still be fairly well defined by from four to six points per wave. Thus values of data at intervals of 6 months are found generally sufficient to fairly well determine, within the limits of accidental deviations, the epochs of maxima and minima of a variable 2½-year wave within about a quarter of a year.

The fact that the January 1 mean embraces contiguous winter months of large departures, taken in connection with the average length of the period, 2 to 2½ years, renders this mean of relatively greater importance than the July 1 mean. This is also shown by the tendency for maxima and minima to occur more frequently in the

[25] Schreiber, P., "Vier Abhandlungen über Periodizität des Niederschlages." Abhand. der Kgl. sächs. meteorl. Institutes. Heft 1 Leipsig, 1896.

period centered on January 1 than in the 12-month mean centered on July 1, in which the winter months stand nearly a whole year apart and will differ in character widely at times.

A nearly ideal preparation of the data would consist of plotting overlapping 12-month means of the ratio, *monthly departures divided by the normal monthly mean deviations of the data*, a treatment which should produce very homogeneous values. However, a trial of this method has not shown sufficiently material differences to justify, especially in a preliminary study like the present one, the great additional labor the use of that method entails.

While, as a rule, the maxima and minima which appear in the curves secured by the methods described are not as well defined as those of the sun-spot curve, nevertheless, at certain stations and for certain elements, the recurrence of these phases fairly approximates, in respect of uniformity of phase interval and amplitude, these features of the solar curve. This is the case, for example, with the pressure at Portland, Oreg., when the secular trend is eliminated and the short period is completely segregated (cf. fig. 1). In some cases when the secular trend is not eliminated the existence of a maximum or minimum phase is indicated only by an inflexion in a continuous ascent or descent of the curve, due to a longer period. The amplitude of the short period is, however, as a rule sufficiently large in comparison with that of the variations of a longer period, as the 7-year period, so that the determination of the phases is quite unaffected by the existence of the longer period. Ordinarily when only the epochs of maxima and minima are desired, allowance can easily be made, by simple inspection, for the secular trend. In doubtful cases one must resort to curves for near-by stations for confirmation, hence it is necessary to have for close comparison curves for a number of stations for any particular region. In this manner instrumental errors, discrepancies due to changes of exposure or location, and the small differences normally occurring between localities more or less widely separated can also be eliminated by a visual comparison of the curves.

The method therefore is essentially that employed by Wolfer in determining the solar epochs, or by astronomers in determining the epochs of maxima and minima of variable stars. The evidence for the reality of the epochs differs only in the degree of certainty from that available for the determination of the solar epochs. The phase-intervals, while being far from uniform, only occasionally show any abrupt changes from short to long, and the amplitude is sufficient to render infrequent such uncertainty as for a long time prevailed regarding the sun-spot interval from 1788 to 1805.

V. THE 28-MONTH PERIOD IN METEOROLOGICAL ELEMENTS

Data employed in the investigation.—In the present investigation I have examined the temperature data in the United States for practically all the stations with long records. The 12-month means centered on January 1 and July 1 were computed and curves drawn for each station. In the years previous to 1830 all available records were employed. Pressure data since 1870 have also been examined for various regions, including the upper Mississippi Valley, the Canadian northwest, Oregon, Washington, British Columbia, and Alaska. In Europe data are available from 1725 for temperature and from 1740 for pressure. From three to six or eight contemporaneous records covering the entire period were plotted for study. In Europe the temperature data employed have been confined to Holland, northern Germany, Sweden, and northern Russia. For reasons which have previously been referred to, northern Europe exhibits the short period more satisfactorily than regions farther south. Similarly in the United States, the middle and upper Mississippi Valley, upper Ohio Valley, and the lake region yield curves with fluctuations more nearly representative of the short period than places farther south or west. The plateau region and Pacific States are characterized by fluctuations with phases differing markedly from those east of the Rocky Mountains.

For pressure, records in Holland, France, Italy, and in later years, Spain have been employed. It is found that southwestern France and western Spain on the whole show the short period most satisfactorily. This may be associated with the fact that the Atlantic high-pressure area projects onto the Continent of Europe over these regions. Other regions studied in detail as regards pressure variations are northern Egypt, India, Australia, Iceland, and Greenland.

The object of the investigation has been to establish by inspection of plotted curves the epochs of maxima and minima for the United States and Europe and to deduce from these epochs the average lag or phase interval between distant regions, and the underlying secular variations in the length of the period, which requires examination of the earliest records available.

For illustrating in more detail the conditions since 1870 there are given in Figure 1 curves representing variations in temperature, pressure, rainfall and other meteorological data at selected stations. The data plotted are 12-month means centered on January 1 and July 1, or two values per year. Several stations in the same region are shown to illustrate the degree of correlation likely to exist between two stations in the regions regarded as best showing the short period. The composite curve of temperature is an average of six stations, viz, Minnedosa, Winnipeg, Bismarck, Moorhead, Duluth, and St. Paul.

Figure 2 represents fluctuations of temperature and pressure previous to 1870. The European temperature curve is a composite of two to five stations, which, with the years of data employed, are as follows: Utrecht, 1729–1739; Leyden, 1740–1753; Berlin, 1730–1751; Åbo, 1750–1761; Lund, 1753–1773; St. Petersburg, 1752–1763, 1768–1800, 1806–1908; Stockholm, 1756–1802; Riga, 1796–1814; Wöro, 1800–1829; Torneo, 1801–1829; Archangel, 1814–1830, 1833–1908; Ustssyssolsk, 1818–1868; Jockmock, 1862–1918. The earlier years include data from Holland and Germany, but from 1750 only data from Sweden and northern Russia were employed. During the whole period of time three to eight contemporaneous curves were available and a section of a curve at any particular station which was markedly at variance with the curves of surrounding stations was rejected in averaging the station departures for the composite curve. Thus the data at St. Petersburg for 1765–1767 were rejected. All other data from the stations above named were used in deriving the composite curve.

For the European pressure curve, data at the following stations were employed, viz: Amsterdam, 1740–1761; Paris, 1758–1853; San Fernando, 1850–1919. This curve therefore represents mainly data from only a single station. As in the case of temperature, several contemporaneous curves were available for study and comparison and these stations for the period of time stated were selected as being most representative of the variations

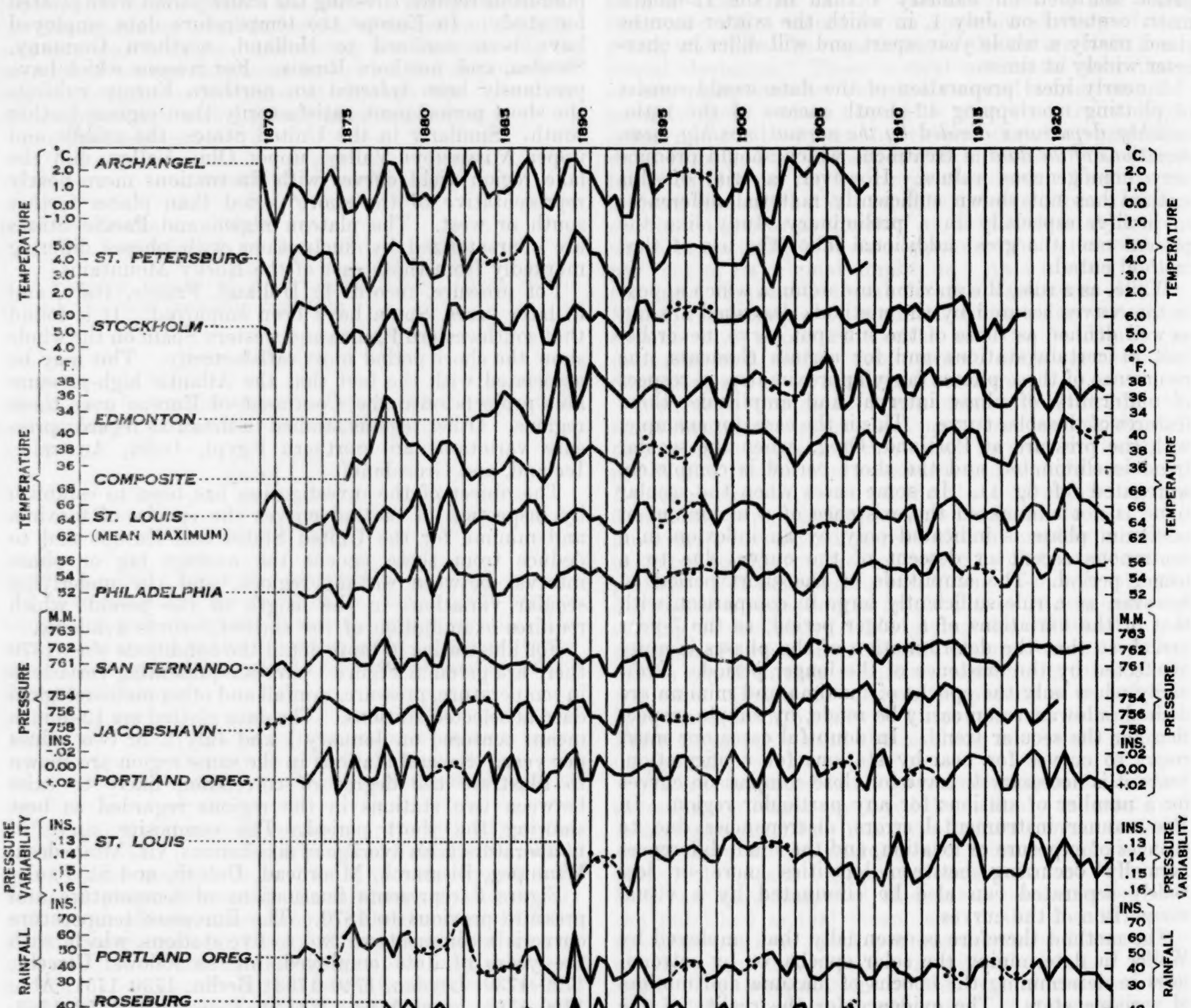


FIG. 1.—Curves representing the 28-month variations, since 1870, in pressure, temperature, rainfall, and pressure variability for selected stations in Europe and the United States, the velocity of areas of low pressure in the United States, and the mean latitude of solar spots. Smooth curves are drawn where minor fluctuations occur. The location of associated phases of temperature, pressure, and latitude of spots is indicated by dots and circles with connecting dotted lines

over southwestern Europe. It is well known that the correlation between the variations in pressure at stations more or less widely separated is considerably greater than the correlation between their variations in temperature, so that the pressure data, if homogenous, from a single station, may yield results entirely representative of a comparatively large region. The pressure data at Paris give internal evidence as well as evidence derived from comparison with other stations as to their fully representative character. Observations at San Fernando were available from 1850 and were regarded, in view of their homogenous character and agreement with neighboring stations, as representative of pressure variations in western Spain. Their correlation with temperature variations in northern Europe is higher than that derived from the pressure data at Paris. Being in 12° lower latitude than Paris, the range of fluctuation is correspondingly less.

For the United States the temperature curve is a composite of the data at the following stations: New Haven, 1780–1828; Salem, 1786–1828; Winslow, Nova Scotia, 1794–1811; Cincinnati (College Hill), 1814–1848; Cincinnati, 1835–1875; Marietta, 1826–1875; St. Louis, 1833–1875. The earlier data are thus drawn mainly from New England. From 1828 the upper Ohio Valley and middle Mississippi Valley contributed to the composite curve, which is thus based on from two to four stations. The range of variation in the Middle West and in Nova Scotia is greater than in southern New England.

Epochs of maxima and minima for the data studied.—Employing the methods previously described, the epochs of minimum temperature and minimum pressure of the short period have been derived for Europe since 1730, and the epochs of both maximum and minimum temperature for the United States since 1780. These epochs are given in Table 1. They have been derived by comparison of all the curves drawn, having due regard at the same time to the secular trend. For this reason the epochs may at times differ slightly from those apparently indicated by the composite curves in Figure 2. The object of the investigation, namely, the determination of the mean length of the period and its secular variations, has been attained in the case of European data in a satisfactory manner by consideration of minima only. Table 1 gives also for each epoch the phase interval from the preceding epoch.

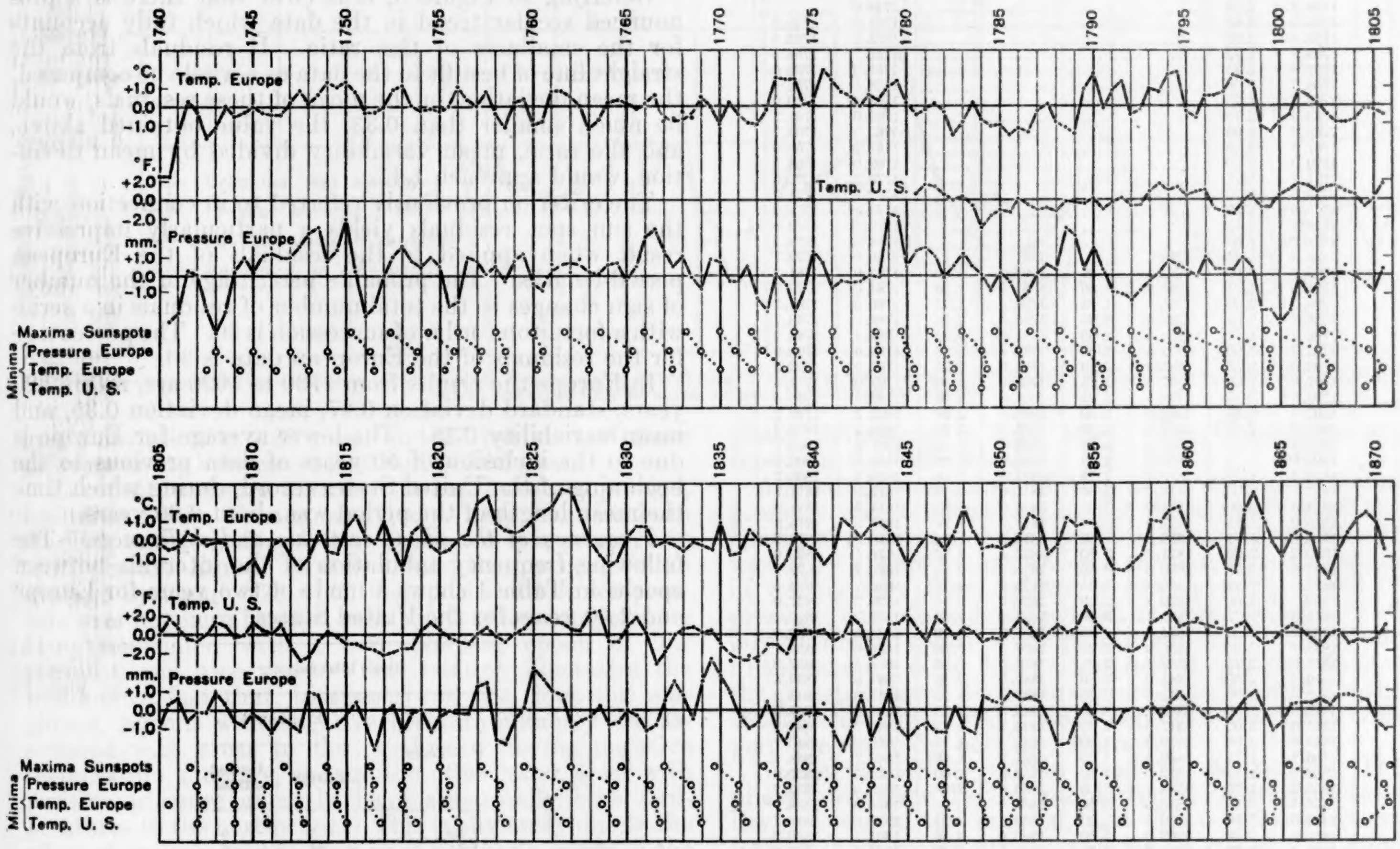


FIG. 2.—Curves (composite) representing the 28-month variations in temperature and pressure in Europe and the United States from 1740 to 1870. The epochs of sun spot maxima and associated phases of temperature and pressure are indicated by circles with connecting dotted lines

The minima of the short period for pressure and temperature in Europe and for temperature in the United States are indicated at the bottom of Figures 1 and 2 by symbols plotted on the dates given in Table 1. These minima are regarded as being associated in a relation of approximate synchronism, and hence as being causally related, in the manner indicated by dotted lines joining the appropriate symbols.

The average interval from maxima to minima is nearly the same as from minima to maxima, and the wave form may therefore be regarded as practically symmetrical.

TABLE 1.—*Meteorological and solar epochs*

Temperature in N. Europe		Temperature in the United States				Pressure in southwestern Europe, minimum	Solar spots, maximum
Minimum	Interval	Minimum	Interval	Maximum	Interval		
1729.0	-	-	-	-	-	-	-
1731.0	2.00	-	-	-	-	-	-
1732.7	1.75	-	-	-	-	-	-
1734.5	1.75	-	-	-	-	-	-
1736.0	1.50	-	-	-	-	-	-
1738.0	2.00	-	-	-	-	-	-
1740.5	2.50	-	-	-	-	-	-
1742.5	2.00	-	-	-	-	-	-
1744.2	1.75	-	-	-	-	1743.0	-
1746.2	2.00	-	-	-	-	1745.0	-
1748.0	1.75	-	-	-	-	1747.0	-
1749.5	1.50	-	-	-	-	1749.0	-
1751.5	2.00	-	-	-	-	1751.2	1750.2
1753.5	2.00	-	-	-	-	1753.7	1752.5
1755.2	1.75	-	-	-	-	1755.7	1754.5
1757.0	1.75	-	-	-	-	1757.2	1756.0
1758.5	1.50	-	-	-	-	1758.5	1758.0
1760.2	1.75	-	-	-	-	1760.5	1760.0
1763.0	2.75	-	-	-	-	1763.0	1761.7
1765.0	2.00	-	-	-	-	1765.2	1763.7
1767.5	2.50	-	-	-	-	1767.2	1766.0
1770.0	2.50	-	-	-	-	1769.0	1768.2
1771.7	1.75	-	-	-	-	1770.7	1770.0
1773.5	1.75	-	-	-	-	1772.2	1771.7
1775.0	1.50	-	-	-	-	1774.0	1774.0
1776.7	1.75	-	-	-	-	1776.0	1776.0
1778.7	2.00	-	-	-	-	1778.5	1778.2
1780.5	1.75	1780.5	-	1781.2	-	1780.0	1779.7
1782.5	2.00	1782.5	2.00	1783.2	2.00	1782.0	1781.2
1784.2	1.75	1784.0	1.50	1784.7	1.50	1784.0	1783.0
1786.2	2.00	1785.7	1.75	1786.5	1.75	1786.0	1784.7
1788.7	2.50	1788.0	2.25	1789.2	2.75	1788.0	1786.7
1790.5	1.75	1790.5	2.50	1791.5	2.25	1789.5	1788.2
1792.5	2.00	1792.5	2.00	1793.7	2.25	1792.0	1790.0
1795.0	2.50	1795.0	2.50	1796.0	2.25	1795.0	1792.2
1797.0	2.00	1797.2	2.25	1798.5	2.50	1797.0	1794.5
1799.5	2.50	1799.5	2.25	1801.0	2.50	1799.5	1796.5
1802.7	3.25	1802.0	2.50	1803.0	2.00	1802.2	1799.2
1805.5	2.75	1804.5	2.50	1805.5	2.50	1804.7	1802.2
1807.2	1.75	1807.0	2.50	1808.0	2.50	1807.0	1804.7
1809.0	1.75	1809.0	2.00	1810.0	2.00	1809.0	1806.7
1810.5	1.50	1810.7	1.75	1811.5	1.50	1810.7	1808.7
1812.5	2.00	1812.7	2.00	1814.0	2.50	1812.5	1811.7
1814.5	2.00	1815.0	2.25	1816.0	2.00	1814.5	1814.0
1816.2	1.75	1817.0	2.00	1817.7	1.75	1816.5	1816.2
1818.0	1.75	1818.5	1.50	1819.5	1.75	1818.0	1818.2
1820.2	2.25	1821.0	2.50	1822.5	3.00	1820.5	1820.0
1823.0	2.75	1823.5	2.50	1825.2	2.75	1823.2	1822.2
1825.7	2.75	1826.7	3.25	1828.0	2.75	1826.7	1824.5
1828.7	3.00	1829.2	2.50	1830.5	2.50	1829.2	1827.0
1831.5	2.75	1831.7	2.50	1833.0	2.50	1831.2	1829.7
1833.7	2.25	1834.0	2.25	1835.0	2.00	1833.5	1832.0
1835.7	2.00	1836.2	2.25	1837.5	2.50	1836.0	1834.7
1838.0	2.25	1838.5	2.25	1839.5	2.00	1838.5	1837.2
1840.5	2.50	1841.0	2.50	1842.0	2.50	1841.0	1839.5
1842.5	2.00	1843.2	2.25	1844.2	2.25	1843.0	1841.2
1845.0	2.50	1845.7	2.50	1846.5	2.25	1845.0	1843.0
1847.0	2.00	1847.5	1.75	1848.2	1.75	1846.7	1845.2
1849.0	2.00	1849.0	1.50	1849.5	1.25	1848.2	1846.7
1850.7	1.75	1850.5	1.50	1851.0	1.50	1849.7	1848.5
1852.5	1.75	1852.0	1.50	1853.0	2.00	1851.5	1850.0
1854.2	1.75	1854.0	2.00	1855.0	2.00	1853.5	1852.2
1856.5	2.25	1856.5	2.50	1858.2	3.25	1856.0	1854.7
1860.0	3.50	1859.5	3.00	1860.5	2.25	1858.7	1857.7
1862.5	2.50	1862.0	2.50	1863.0	2.50	1861.5	1860.2
1864.7	2.25	1864.2	2.25	1865.5	2.50	1864.5	1862.5
1867.5	2.75	1866.7	2.50	1868.0	2.50	1867.5	1865.2
1870.7	3.25	1869.5	2.75	1871.0	3.00	1870.5	1868.7
1873.2	2.50	1872.7	3.25	1874.2	3.25	1872.7	1870.7
1875.2	2.00	1875.2	2.50	1876.0	1.75	1875.0	1872.7
1877.0	1.75	1877.0	1.75	1878.0	2.00	1877.0	1874.7
1879.0	2.00	1879.0	2.00	1880.0	2.00	1879.0	1877.2
1881.0	2.00	1881.0	2.00	1882.0	2.00	1881.0	1880.0
1883.0	2.00	1883.2	2.25	1884.5	2.50	1883.0	1882.0
1885.7	2.75	1885.5	2.25	1886.7	2.25	1885.5	1884.0
1888.2	2.50	1888.0	2.50	1889.5	2.75	1887.7	1885.7
1891.0	2.75	1890.2	2.25	1891.5	2.00	1890.5	1888.2
1893.2	2.25	1893.2	3.00	1894.5	3.00	1892.5	1891.5
1896.2	3.00	1896.5	3.25	1898.0	3.50	1895.5	1893.7
1899.5	3.25	1899.0	2.50	1900.2	2.25	1899.0	1896.0
1902.5	3.00	1901.5	2.50	1902.5	2.25	1901.7	1898.2
1904.7	2.25	1904.0	2.50	1906.0	3.50	1904.5	1900.7
1907.2	2.50	1907.2	3.25	1908.5	2.50	1907.0	1903.7
1909.2	2.00	1909.5	2.25	1910.5	2.00	1909.5	1906.7
1912.5	3.25	1912.0	2.50	1913.5	3.00	1912.0	1909.2
1915.5	3.00	1914.5	2.50	1916.0	3.00	1915.0	1912.5
1917.2	1.75	1917.2	2.75	1919.0	2.50	1917.0	1915.5
1919.5	2.25	1920.0	2.75	1921.2	2.25	1919.2	1918.0
1922.2	2.75	1922.5	2.50	1924.0	2.75	1921.2	1920.2
-	-	-	-	-	-	1924.0	-

NOTE.—The tenths .2 and .7 in the dates stand for .25 and .75 respectively.

The mean length of the period and analysis of its variations.—The result of the United States series from 1780 to 1920 yields an average interval of 2.33 years between like phases, with a probable error, derived from the mean deviation, of ±.038 year. The standard deviation of the 61 intervals between successive minima is 0.43 year, the mean deviation 0.33, and the mean variability, or the mean change between successive values is 0.32 year. Analyzing these measures of dispersion and of the order of succession we notice that the standard deviation is 1.29 times the mean deviation. Since this ratio agrees very nearly with Cornu's ratio, 1.25, we may conclude that the distribution is nearly according to the Gaussian curve. The mean variability (0.32) divided by the mean deviation (0.33) is 0.97, a ratio so much smaller than Goutereau's ratio 1.41, that we must conclude that the order of succession of the numbers can not be fortuitous or unrelated, but rather is determined by some physical cause or influence not yet known.

Referring to Figure 3, it is clear that there is a pronounced secular trend in the data which fully accounts for the smallness of this ratio. If residuals from the straight line of best fit to the data as a whole be computed, the mean deviation, or the mean of these residuals, would be much smaller than 0.33, the value obtained above, and the ratio, mean variability divided by mean deviation, would approach 1.41.

The criterion previously referred to in connection with the sun spot residuals yields a particularly impressive result when applied to the residuals of the European period-lengths. The probable percentage of the number of sign changes to the total number of residuals in a series with a fortuitous order of succession is 50. The percentage for the residuals of the European data is 30.

In Europe the results from 1730 to 1920 are, mean 2.20 years, standard deviation 0.47, mean deviation 0.39, and mean variability 0.38. The lower average for Europe is due to the inclusion of 50 years of data previous to the beginning of the United States record, during which time the mean length of the period was about 2.00 years.

Frequency of the phase intervals and differences.—The following frequency tabulation of the intervals between epochs in Table 1 shows a mode of two years for Europe and 2.50 years for the United States.

Phase intervals

Years	Frequencies: Europe	Frequencies: United States
1.50	5	9
1.75	22	9
2.00	23	21
2.25	8	23
2.50	12	38
2.75	8	7
3.00	4	7
3.25	4	6
3.50	1	2
Total	87	122

Differences, Europe—United States

Years	Frequencies
−1.00	1
−0.75	4
−0.50	9
−0.25	8
0.00	16
+0.25	6
+0.50	8
+0.75	5
+1.00	3
+1.25	1

A frequency tabulation of the differences between the European and the United States epochs is also shown above. The mean difference is +0.05 year, which means that the epochs of maxima and minima are, in the long run, practically coincident in the two continents. The

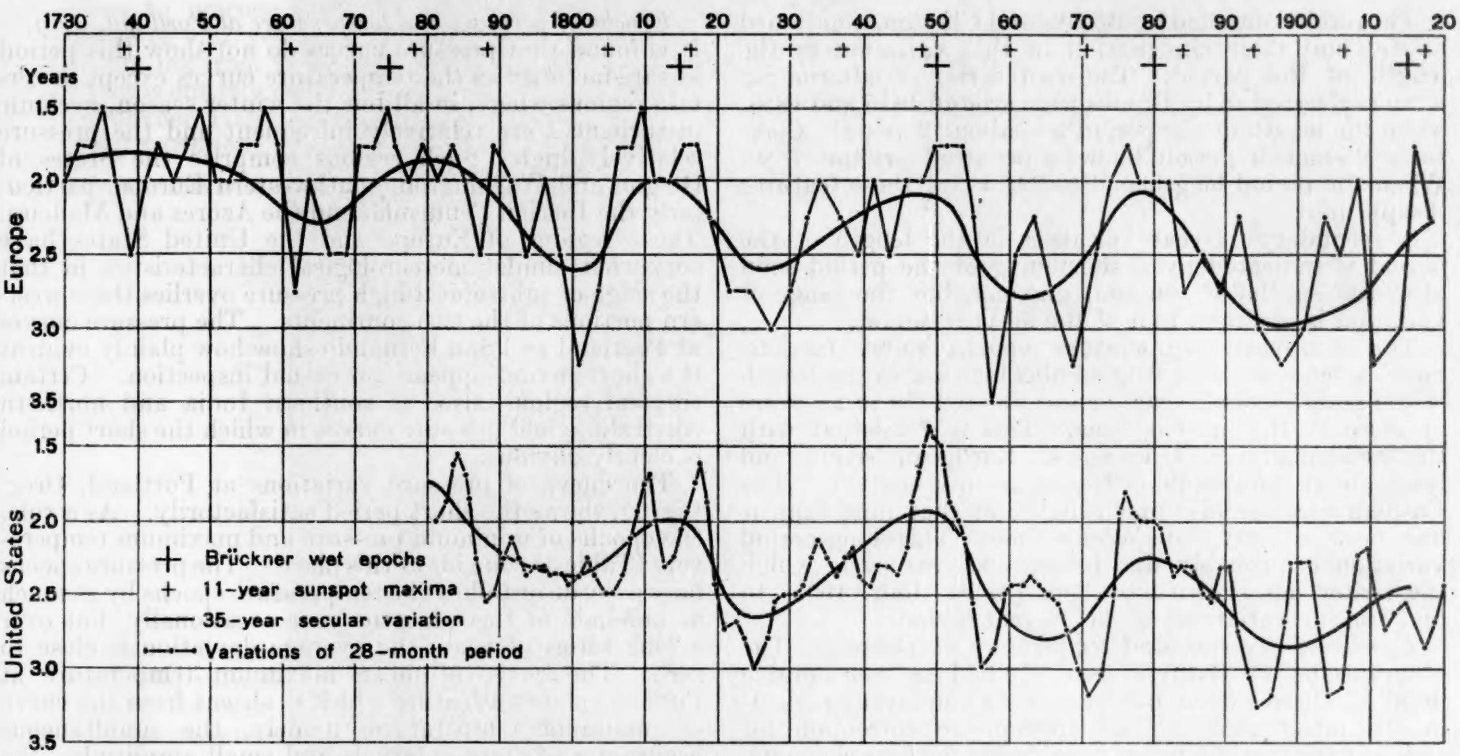


FIG. 3.—Curves representing the variation in the length of the 28-month period derived from the epochs of temperature for Europe and the United States (Table 1). The heavy smooth curve represents the 36-year variation in the length of the period

mean deviation is 0.39 year, and 77 per cent of these differences are between +0.50 and −0.50 year.

European pressure data for the southwestern portion, including Spain, France, and Italy, have likewise been studied, and it is found that epochs of low pressure in southwestern Europe (Table 1) usually precede, on an average by about 0.28 year, the epochs of low temperature over northern Europe, each epoch of low temperature being associated with a corresponding epoch of low pressure, and vice versa. This relation illustrates the well-known fact that, irrespective of the time unit employed, regions with negative pressure anomaly are associated with areas to the northward having negative temperature anomaly, and, on the other hand, areas with positive pressure anomaly have abnormally high temperatures to the northward. This is obviously due to the effect of an increased frequency of northerly winds in the first case and of southerly winds in the second.

The table below gives the frequencies of occurrence of the various differences between these epochs (pressure epochs minus temperature epochs), from which it appears that for Europe the mode is slightly greater than 0.0, and the mean deviation 0.44 year.

Differences, pressure—temperature		
Years	Frequencies	
	Europe	United States
−1.00	1	1
−0.75	0	1
−0.50	5	2
−0.25	10	5
0.00	17	19
+0.25	14	11
+0.50	13	14
+0.75	8	6
+1.00	8	3
+1.25	4	----------

The epochs of minimum temperature in the United States average 0.22 year later than the epochs of minimum pressure in Europe. The mean deviation of the phase differences is 0.34 year. The frequencies are shown in the table above.

Advantage was taken of this close relation between pressure and temperature in the determination of the epochs of maxima and minima of these two elements. It was early apparent that for each maximum or minimum of temperature there existed a corresponding phase of pressure, and where doubt existed as to the assignment of any particular epoch of temperature reference was made to the pressure curve for confirmation or change. In fact the pressure curve for southwestern Europe exhibits the short period with even greater regularity than the temperature curve for northern Europe.

Secular variations in the length of the period.—The phase intervals in Table 1 are plotted in Figure 3 opposite the midyear of the interval, and the continuous curve joining them represents the varying length of the period since 1730. The curve for the United States represents both maximum and minimum phase intervals smoothed by the formula $(a+2b+c)\div 4$. The Brückner wet epochs and the epochs of sun spot maxima are shown on the diagram. The 36-year secular variation in the length of the period is shown by the heavy smooth curve.

Inspection of this diagram discloses a tendency to minimum lengths of the period about 1750, 1780, 1815, 1850, 1880, and 1915, and to maximum lengths at the intermediate dates. These dates when the period is short coincide with the Brückner epochs of maximum precipitation in the interior of the United States and Europe. In other words, when the period length is 2 years or less, excessive precipitation over a period of years occurs, and when the length is 3 years or more a deficiency in precipitation occurs. A relation analogous to this was deduced by the writer from a study of the sun spot period. He showed (Astro. Jour., 1905) that a shortening of the period to 10 years or less preceded by about 10 years the Brückner epochs of excessive rainfall, and vice versa, a length of the period above the average, as 12 to 14 years, preceded epochs of deficiency of rainfall.

The results obtained by Brooks and Clayton, mentioned above, find their explanation in this variation in the length of the period. The two series of alternating winters referred to by Brooks were around 1815 and 1880, when the length of the period was about 2 years. Clayton's 25-month period likewise occurred around 1880. When the period lengthened to 2¾ years these features disappeared.

A secondary 11-year variation in the length of the period is indicated by a shortening of the period soon after the epochs of sun spot maxima, but the range of variation is less than that of the 36-year period.

The European temperature epochs show, furthermore, a tendency to a long secular increase in the length of the period from 2 years or less about 1750 to 2.5 years or more at the present time. This is consistent with the abnormally high levels of European rivers and lakes about the middle of the eighteenth century. The Caspian Sea was also much higher at that time than it has been at any subsequent time. This long-period variation is probably due to the 300-year cycle which the writer has shown elsewhere (Astro. Jour. 1905) to underlie the variations of the 36-year period.

Epochs of pressure and temperature at Batavia.—The observations at Batavia were studied in considerable detail. Three means per year were employed, each 4-month mean receiving an appropriate correction for annual variation. Curves were drawn for four elements, viz, pressure, mean maximum temperature, mean minimum temperature and rainfall, the latter element being expressed in the form of a frequency of occurrence, using the number of months with deficient precipitation in each 12-month period centered on January and July 1. By comparison of these four curves it was possible to determine definitive epochs for this place since 1866. The epochs of maximum and minimum pressure coincide closely with the epochs of minimum and maximum frequency of rainfall respectively. The epochs of the mean maximum temperature follow similar phases of the pressure by about 4 months as an average. The epochs of the mean minimum temperature follow by a few months the epochs of the mean maximum temperature. Table 2 gives the epochs of pressure and mean maximum temperature for this place. The fluctuations of pressure are entirely representative of the fluctuations for the whole Indo-Oceanic region, including India, Australia, and Mauritius.

TABLE 2.—*Epochs of maximum and minimum pressure and temperature at Batavia*

Pressure		Mean maximum temperature	
Maximum	Minimum	Maximum	Minimum
----------	1867.2	----------	1867.5
1868.5	1870.2	1868.7	1870.7
1871.5	1872.8	1871.5	1872.2
1873.8	1875.0	1873.8	1874.7
1875.5	1876.3	1875.7	1877.0
1877.5	1878.7	1877.7	1879.5
1879.4	1880.0	1880.0	1880.7
1881.2	1882.3	1881.8	1882.5
1883.7	1884.5	1883.5	1885.0
1885.7	1887.2	1885.7	1887.7
1888.7	1890.0	1889.0	1890.7
1891.5	1892.5	1891.8	1893.8
1894.2	1895.5	1894.7	1895.5
1896.7	1898.5	1897.2	1899.0
1899.8	1901.3	1900.5	1901.5
1902.8	1904.2	1903.0	1904.6
1905.5	1906.8	1906.0	1907.0
1908.5	1910.2	1908.8	1910.2
1911.7	1913.2	1912.2	1913.0
1914.5	1916.7	1914.8	1916.8
1917.5	----------	1917.5	----------

Epochs of pressure and temperature at Portland, Oreg.—It is found that pressure curves do not show this period as satisfactorily as the temperature curves except in certain regions where, in all but the winter season, cyclonic disturbances are relatively infrequent and the pressure relatively high. Such regions comprise the States of Oregon and Washington, southwestern Europe, particularly the Iberian Peninsula, and the Azores and Madeira. These regions of Europe and the United States have somewhat similar meteorological characteristics in that the ridge of subtropical high pressure overlies these western portions of the two continents. The pressure curves at Portland and San Fernando show how plainly evident the short period appears on casual inspection. Certain tropical regions also, as southern India and northern Australia, yield pressure curves in which the short period is clearly obvious.

The curve of pressure variations at Portland, Oreg. (fig. 1), shows the short period satisfactorily. As a rule, the epochs of minimum pressure and maximum temperature (Table 3) coincide at this place. The pressure epochs may precede or follow the temperature epochs by as much as one-half or three-fourths year occasionally, but over a long series of years the average deviation is close to zero. The curve of mean maximum temperature at Portland shows a feature which is absent from the curve of minimum temperature, namely, the simultaneous occurrence of short intervals and small amplitudes, the amplitude being a direct function of the length of period. The mean length of the period about 1880 was 1.8 years, and the extreme range averaged 1°.5. In 1890 the mean length had increased to 2.9 years and the range to 3°.5. In 1910 the mean length was 2.5 years and the range 1°.5. In 1920 the length was 3.0 years and the range 3°.5. As previously stated, the amplitude by the method employed is reduced to about 68 per cent. These values of the range should therefore be increased by about one-half to obtain the true range.

TABLE 3.—*Epochs of pressure and temperature at Portland, Oreg.*

Pressure		Temperature	
Maximum	Minimum	Minimum	Maximum
1873.0	1874.2	1872.5	1874.2
1875.0	1876.0	1875.0	1876.0
1877.0	1878.0	1877.0	1877.5
1879.0	1879.7	1878.7	1879.5
1880.7	1882.0	1880.2	1881.2
1883.0	1884.2	1882.0	1883.2
1885.0	1886.0	1884.5	1885.5
1887.7	1889.5	1887.5	1889.0
1890.7	1891.5	1890.2	1891.7
1893.0	1894.2	1893.5	1894.7
1895.7	1896.7	1896.0	1897.5
1898.5	1900.0	1899.0	1900.0
1901.5	1902.5	1901.0	1902.5
1903.5	1904.7	1903.5	1905.0
1906.0	1907.0	1906.0	1907.2
1908.5	1909.5	1909.0	1910.2
1911.0	1912.5	1911.2	1912.2
1913.5	1915.2	1913.5	1915.0
1917.2	1919.0	1916.7	1918.0
1920.0	1921.0	1920.0	1921.0
1922.0	1923.0	1922.5	1924.0
1924.5	----------	----------	----------

Epochs of pressure for Greenland and Iceland.—Pressure data are available for Iceland since 1846 and for Greenland from 1842 to 1851 and since 1866. A curve of these variations in pressure at Jacobshavan, Greenland, since 1870 is shown in Figure 1. In general the epochs for Greenland and Iceland closely agree. Table 4 gives the epochs based on the Jacobshavn data except from 1850 to 1866, when they are derived from the Iceland data. Comparison with the epochs of minimum temperature in Europe shows a tendency for high pressure in the Arctic

regions to precede low temperature in Europe by an average of 0.27 year. The mean deviation of the temperature lag from this average value is 0.28 year. This relation is entirely confirmatory of similar relations found by Brückner, Hann, and others for both cyclical and noncyclical variations.

TABLE 4.—*Epochs of maximum and minimum pressure in Greenland and Iceland*

Maximum	Minimum	Maximum	Minimum
1844.5	1845.5	1882.5	1884.0
1846.5	1847.5	1885.7	1886.7
1848.7	1849.5	1888.0	1890.0
1850.2	1851.0	1891.0	1891.5
1852.0	1852.5	1892.5	1894.2
1853.2	1854.5	1896.2	1898.5
1856.0	1857.5	1899.7	1901.0
1859.5	1860.0	1902.2	1903.0
1861.7	1863.0	1904.5	1905.5
1865.0	1866.2	1907.2	1908.5
1867.0	1868.0	1910.0	1911.5
1869.7	1872.0	1912.5	1913.5
1872.7	1874.2	1915.5	1916.5
1875.0	1875.7	1917.5	1918.2
1876.7	1877.7	1919.2	1920.5
1878.5	1880.0	1922.5	----------
1881.0	1882.0	----------	----------

Epochs of pressure variability at St. Louis.—The mean interdiurnal variability of pressure at St. Louis has been computed for each month from 1888 to 1923, inclusive. Both 8 a. m. and 8 p. m. observations have been employed for this purpose. A curve showing variations in this element is shown in Figure 1, and the 28-month epochs of maxima and minima are given in Table 5. The epochs of maximum and minimum variability precede, respectively, the epochs of minimum and maximum temperature by an average of 0.30 year. Correlation of these variations with the temperature at Winnipeg in winter yields −.57, while with the temperature at New Orleans the correlation is +.40. The inference is that large day to day changes in pressure at St. Louis are associated with temperature below normal to the northward, and temperature above normal to the southward. The latitudinal temperature gradient at such times is increased and areas of high and low pressure move more rapidly. This is shown by the correlation between the pressure variability and the velocity of movement of low pressure areas in the United States during the months December to March, which amounts to +.45.

TABLE 5.—*Pressure variability at St. Louis*

Maximum	Minimum	Maximum	Minimum
----------	1889.0	1906.5	1907.5
1890.2	1891.7	1908.7	1910.5
1893.5	1894.7	1911.7	1913.5
1896.0	1897.5	1914.5	1915.2
1898.5	1900.0	1917.0	1919.0
1901.0	1902.2	1920.0	1921.0
1904.0	1905.2	1923.0	----------

Velocity of movement of areas of low pressure.—The mean velocity of low-pressure areas over the United States from 1872 is shown in Figure 1. The curve is inverted to show the inverse correlation between temperature, particularly in high latitudes, and the mean velocities of storms. The curve of temperature at Edmonton, for example, shows a high correlation with the velocity curve. Table 6 gives the epochs of the short cycle.

TABLE 6.—*Epochs of maximum and minimum velocity of Lows*

Maximum	Minimum	Maximum	Minimum
----------	1873.0	1888.2	1889.5
1875.2	1876.0	1890.2	1891.2
1877.0	1878.0	1893.0	1894.7
1879.5	1880.5	1896.5	1997.5
1881.5	1882.7	1898.5	1899.5
1883.5	1884.0	1900.5	1901.2
1885.0	1886.2	1903.0	----------

Variations of rainfall and lake levels and correlation with pressure and temperature.—The close relation between pressure and temperature in Europe, shown above, is clearly due to the intimate relation between wind direction and temperature. An increase in the northerly component at the surface is associated with pressure below normal over southern Europe, and vice versa. With rainfall, however, the relation is more complicated. An excess of rainfall, for example, involves more than one factor. There must be (1) an excess of water vapor in the atmosphere which is usually due to the prevalence of winds with a southerly component and from a water surface; (2) the occurrence of cyclonic conditions which are favorable to the general ascent of vapor-laden air and consequent dynamic cooling and condensation. These two factors do not usually coexist in northern Europe, since the prevalence of winds from the Atlantic is favored by high pressure over central and southern Europe and low pressure over Iceland; in other words, anticyclonic conditions exist over Europe, which are unfavorable to the occurrence of general ascent of air. Although the vapor content of the air may be high, the absence of the requisite condition for its abundant condensation results in only moderate rainfall.

These considerations largely account for the fact that rainfall data do not exhibit the short period as regularly and definitely as pressure and temperature. Statistical analyses, moreover, have shown that rainfall data are more nearly allied to perfectly fortuitous data than other elements, and for this reason it is probable that rainfall, the importance of which is greater than that of temperature, will never be as satisfactorily forecast as will temperature.

Epochs of maxima and minima of rainfall at Upsala and of the level of Lake Malar have been assigned and the lake epochs are given in Table 7. The epochs of lake level follow by about 0.2 year the epochs of rainfall. As a rule, the epochs of maximum lake level usually precede slightly the epochs of minimum pressure, the average interval being 0.10 year; but at times, notably around 1845 and 1880, they are nearly coincident with or even follow the pressure epochs. The rainfall curve shows numerous secondary maxima and minima, due partly, as above stated, to the presence of periods shorter than the 28-month period and partly to merely minor accidental features or imperfectly eliminated or abnormal annual variation. For this reason Wallén derived a period of only 24 months for the rainfall as against 30 months for the lake levels. The epochs of lake level assigned by me differ from Wallén's in some respects. I have inserted three additional maxima, only slightly developed, and combined two of his adjacent maxima into one. These changes reduce the mean length of the period to 28 months, which is also the mode for this lake, as before stated.

TABLE 7.—*Epochs of high and low water in Lake Malar*

High	Low	High	Low
1825.0	1826.7	1870.0	1871.8
1828.0	1830.0	1872.9	1874.5
1831.0	1832.8	1875.0	1875.7
1834.0	1835.6	1877.5	1878.5
1836.5	1837.8	1879.5	1880.4
1838.7	1840.0	1881.8	1883.0
1841.6	1843.0	1883.8	1884.7
1843.5	1844.1	1885.7	1887.0
1844.7	1845.5	1888.5	1889.5
1846.2	1847.1	1890.5	1892.8
1848.5	1849.5	1894.0	1895.0
1850.2	1851.0	1896.0	1897.5
1851.7	1852.3	1898.7	1899.9
1853.2	1854.0	1900.8	1901.9
1855.2	1856.0	1903.5	1905.0
1857.5	1859.5	1906.0	1907.0
1860.6	1862.0	1907.9	1909.0
1863.5	1865.5	1910.5	----------
1867.0	1868.7		

For reasons previously stated, the lake variations are regarded as more suitable for the determination of the epochs of the short period than rainfall variations, and these epochs are therefore regarded as representative of the rainfall variations in Sweden. In other countries, however, an entirely different régime may prevail.

The rainfall for Oregon varies in a fairly regular manner in the 28-month period. Curves showing the rainfall variations for Portland and Roseburg are shown on Figure 1. The epochs of minimum and maximum rainfall for Oregon coincide closely with the epochs of maximum and minimum pressure, respectively, at Portland, there being an average lag or retardation of 0.13 year in the rainfall epochs. This relation is similar to the result found for Sweden, and also to that for Batavia.

Correlations of temperature in the Mississippi Valley and lag between northern and southern stations.—The epochs of the short period for St. Paul, St. Louis, Memphis, Vicksburg, and New Orleans have been derived, and it is found that there is an average lag of 0.19 year from St. Paul to St. Louis, and a lag of 0.37 year between St. Paul and New Orleans. From St. Louis to New Orleans there is a lag of 0.20 year. The short-period fluctuations thus occur later in low latitudes.

This is confirmed by the correlation coefficients for St. Paul and Vicksburg, employing 12-month means, 6 months apart. With simultaneous values the coefficient is +0.34. With Vicksburg temperatures, 6 months previously, the coefficient is −0.26, and a year previous, −0.38. On the other hand, with Vicksburg temperatures 6 months later the coefficient is +0.48, or considerably greater than for simultaneous temperatures.

The inference is that the waves of high and low temperature travel equatorward over North America. The amplitude at southern stations is also much less than that at northern stations. Whether the lag at southern stations is a universal phenomenon is for further investigation to determine, but it may be stated that Clayton's[26] researches lead him to a similar inference.

VI. THE 28-MONTH PERIOD IN SOLAR PHENOMENA

Bigelow and Lockyer endeavored to correlate variations in the frequency of solar prominences with meteorological variations. The prominence data, are, however, unsatisfactory, owing to the necessary limitation of the observations to the solar limb and to the lack of homogeneity in the data by different observers.

Variation in mean latitude of sun spots.—The variations of the mean solar latitude of the entire spotted area as measured by the Greenwich Observatory since 1875 comprise a homogeneous body of data which exhibits the short period very satisfactorily. The data published are means during successive synodic rotation periods of the sun, employing the period deduced by Carrington, 27.27 days. I have averaged the data by groups approximating the periods January 1 to June 30 and July 1 to December 31, to obtain two means per year. These are shown in Table 8. The plus signs represent north latitude and the minus signs south latitude. Column 1 is the first half and column 2 the second half of the year.

TABLE 8.—*Mean solar latitude of entire spotted area, in degrees*

	(1) January-June	(2) July-December		(1) January-June	(2) July-December
	°	°		°	°
1874	----------	−3.7	1900	−1.6	−1.6
1875	+1.6	+1.4	1901	−1.4	−2.4
1876	−4.1	−4.6	1902	+16.0	+6.0
1877	−2.3	−1.6	1903	+4.7	−4.0
1878	+7.2	+6.2	1904	+0.7	+1.3
1879	−10.3	−3.3	1905	−1.7	+3.3
1880	+9.4	+5.2	1906	+6.1	−0.1
1881	−2.7	+10.7	1907	−4.5	−2.0
1882	−5.7	+1.7	1908	−4.3	+2.0
1883	−5.6	−6.9	1909	−2.9	−3.3
1884	−4.0	+0.1	1910	−4.0	−5.6
1885	−4.6	−2.2	1911	−3.3	+0.0
1886	−7.1	−2.4	1912	−10.0	−4.5
1887	+2.3	−4.3	1913	+15.0	+6.6
1888	−4.4	−5.0	1914	+7.1	+3.1
1889	−1.5	−10.0	1915	+5.2	−0.7
1890	+2.1	−0.3	1916	+0.4	+9.6
1891	+2.4	+9.4	1917	−0.3	+0.5
1892	−3.7	−2.8	1918	+1.9	−0.5
1893	−6.1	−2.0	1919	+0.6	−2.4
1894	−4.3	−2.3	1920	−0.3	−3.1
1895	+3.3	+3.2	1921	−1.0	+3.0
1896	−4.1	−6.0	1922	+4.0	−3.6
1897	−3.5	+0.1	1923	----------	----------
1898	−6.0	−4.7	1924	----------	----------
1899	−7.8	−6.3			

A sudden shifting of the excess of spots from southern to high northern latitudes occurs shortly after the spot minimum, resulting in a pronounced 11-year variation in the mean latitude. I have eliminated this 11-year variation by taking residuals from a smooth curve representing the secular trend, and a plot of these residuals, slightly smoothed is shown in Figure 1. This curve shows the pure 28-month variation and may be readily compared with meteorological curves. The epochs of this variation are given in Table 9, representing the mean dates when excesses of spots occurred alternately in the two hemispheres. The average length of the period between 1875 and 1924 is 2.55 years, varying from 2.2 years in 1880 to 2.9 years in the late nineties and then decreasing to 2.5 years about 1915 to 1920.

TABLE 9.—*Epochs of solar spot variation in latitude*

North	South	North	South
1875.7	1877.0	1900.2	1901.5
1878.5	1879.2	1902.5	1903.7
1880.2	1881.2	1906.0	1907.5
1882.0	1883.5	1908.7	1910.2
1884.7	1886.0	1911.7	1912.5
1887.2	1888.2	1914.0	1915.5
1889.2	1889.7	1916.7	1917.5
1891.7	1893.2	1919.0	1920.5
1895.5	1896.5	1922.0	1922.7
1897.7	1899.2	1924.2	----------

Employing the method of correlation illustrated in Section II by the data at St. Paul, the following table gives for the solar data plotted in figure 1 the results of correlating values of the same data separated by successive time units, in this case half-yearly intervals.

[26] Clayton, H. H., World Weather, 1924, p. 260.

Years	r	years	r
0.0	+1.00	3.0	−.18
0.5	+.36	3.5	−.14
1.0	−.76	4.0	−.11
1.5	−.52	4.5	+.49
2.0	+.46	5.0	+.19
2.5	+.48		

The maximum positive coefficients are at 2.25 and 4.5 indicating a length of period of about 2.25 years.

Variation in Wolfer's relative sun-spot numbers.—To extend the solar epochs back from 1875, I have plotted the Wolfer sun-spot numbers (smoothed) beginning with 1750, and also the 6-month means, January to June and July to December, inclusive. Through the minor fluctuations superposed upon the 11-year period a smooth curve was then drawn forming the primary 11-year wave. Thus it was possible to determine from these curves, which facilitated elimination of the secular trend, the epochs of secondary spot maxima and minima, and while these epochs are not wholly satisfactory, owing to the approximate character of the data, especially in earlier years, yet it is clear that the 28-month period is present in these secondary fluctuations and has persisted since 1750, and that its length has varied synchronously with that of the meteorological period. These epochs of spot maxima are given in Table 1.

The following table gives the frequency of the intervals, which have varied between 1.5 and 3.5 years.

Interval	Cases	Interval	Cases
1.50	7	2.75	5
1.75	12	3.00	7
2.00	14	3.25	1
2.25	17	3.50	3
2.50	10		

The mean length is 2.27 years, while the mode is approximately 2.15 years. The distribution is somewhat unsymmetrical and similar to that of the 11-year period. The mean deviation is 0.38 year and the mean variability 0.41 year.

VII. CORRELATION OF SOLAR AND METEOROLOGICAL DATA

When a curve of the solar variations in latitude is compared with a curve of terrestrial data, as, for example, the temperature at St. Paul, it is apparent that each epoch of low temperature is preceded by a corresponding epoch of spot excess in the Northern Hemisphere, the average interval of time intervening, or the time-lag, being about 1.00 year. This time-lag, being a direct function of the length of the period, varies, being about three-fourths year in 1880 and 1915 when the period length is short, and 1⅓ years in 1895. (Cf. fig. 4.) Correlating the solar and temperature data for the period 1875-1923 for simultaneous values and also for successive lags, varying by half-yearly intervals, in the temperature, the following results are obtained. For simultaneous values the result is set opposite zero in the table; shifting the temperature curve to the left by successive half-yearly intervals the results are as shown:

Years	r	Years	r
0.0	+.40	3.0	−.63
0.5	−.51	3.5	+.15
1.0	−.56	4.0	+.60
1.5	+.26	4.5	+.31
2.0	+.60	5.0	−.50
2.5	+.15	5.5	−.31

This table shows that the phases of the two curves come into approximate conjunction or opposition with each other, as the temperature curve is shifted by successive half-yearly intervals, on an average of about every 2¼ years.

When the sunspot epochs from 1750 are compared with the European epochs of low pressure (fig. 2), it is clear that there is a remarkable correspondence in the two series. The solar epochs precede the meteorological epochs by an average interval of 1.6 years. The time interval varies widely in a 36-year cycle, ranging from near coincidence when both phase intervals are short, or around 1750, 1775, 1815, 1845, 1880, to 3 years or more when the phase intervals are long. Here, as elsewhere, the time interval or lag is a direct function of the length of the periods.

Since 1875, when the latitude variation data become available, these epochs are to be preferred to the epochs of spot maxima as representative solar data to be correlated with the meteorological epochs. The epochs of excess spottedness in the Northern Hemisphere precede the epochs of low pressure in Spain by an average of 0.9 year, and the epochs of high pressure at Portland, Oreg., by about 0.6 year.

VIII. GRAPHICAL EVALUATION OF THE LENGTH OF A VARIABLE PERIOD

Figure 4 is a diagrammatic representation of a periodicity tabulation of the mean latitude of spots with only the secular variation eliminated. The dates at the left are given at intervals of 2½ years beginning with 1872.5. The vertical lines are one year apart. Beginning with each date 1872.5, 1875.0, etc., the data are plotted for five years so that the second half of each curve is identical with the first half of the next curve. The epochs of maximum north and south latitude are indicated on the line of zero latitude for each section and curves of best fit have been drawn through these points. These curves of best fit incline to the left until 1885–1890, indicating a length of period less than 2½ years, thereafter to the right, indicating a mean length greater than 2½ years. In recent years the line inclines slightly to the left again. The curve of best fit for the minima has the same general course as the curve for the maxima, but their distance apart is least around 1880 when the slope of the curves indicates that the length of the period is shortest. The spread gradually increases until about 1895, then decreases to about 1915–1920.

A further feature is an 11-year variation in the length of the period, superposed on the long 36-year variation. Shortly after the epochs of spot minima, indicated on the diagram, the maxima of the curves are far to the left of the line of best fit, while on the next recurrence the maximum has shifted over to the right, indicating an excessively long interval at that time.

This graphical scheme is an extension of the familiar numerical periodicity tabulation combined with the well-known shift of phase when the length of the period differs somewhat from the time covered by a single row of the tabulation.[27]

The epochs of minimum temperature for the United States are shown plotted on Figure 4 with the curve of best fit drawn. This curve follows the curve of north latitude of spots by about one year as an average, but the spread of the two curves varies directly with the length of the period in a 36-year cycle.

[27] Cf. Brunt. Combination of Observations, p. 199.

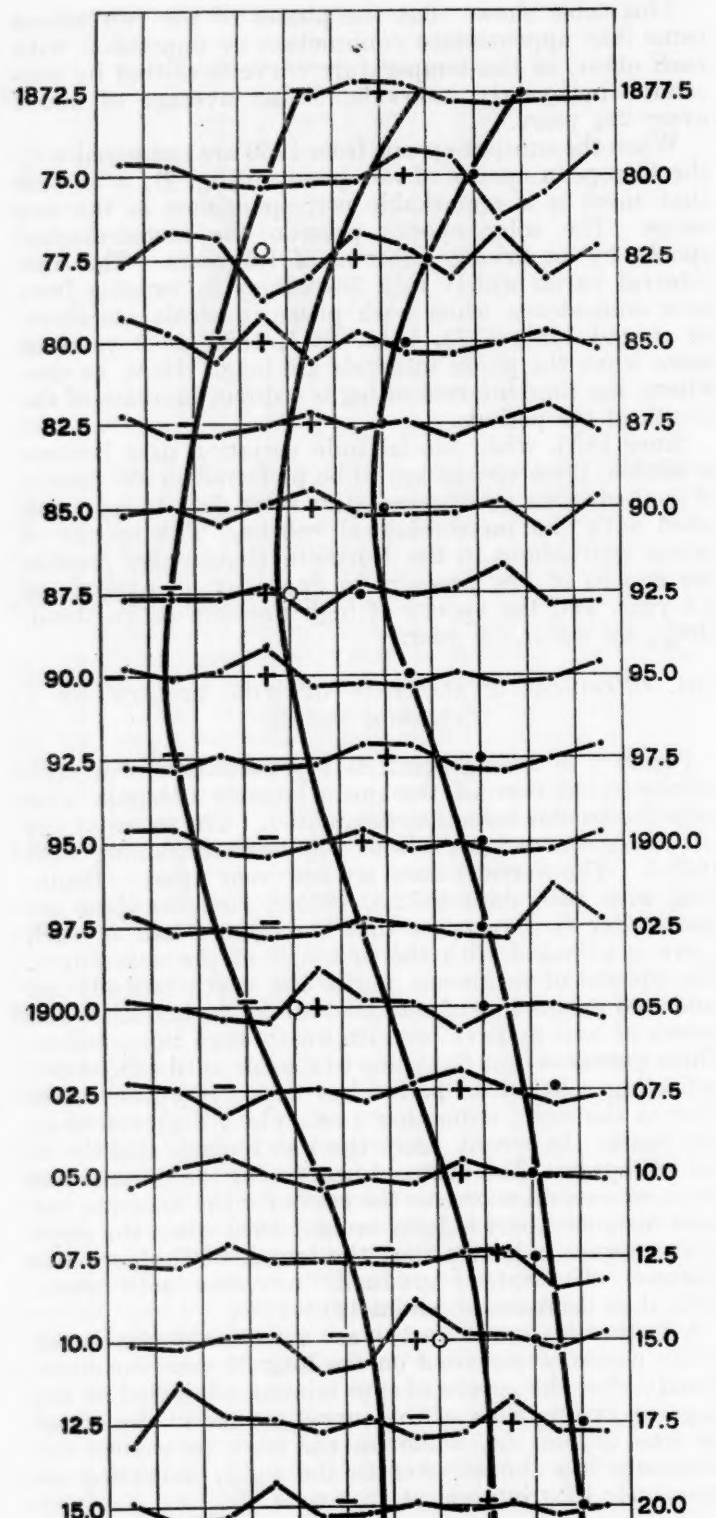


FIG. 4.—Graphical periodicity tabulation of mean latitude of sun spots, with a fundamental interval of 30 months. The horizontal curves comprise a time interval of 60 months. The vertical curves are curves of best fit drawn through the points on the axis of each horizontal curve, which represent the locations of the phases of maxima and minima of the 28-month period.

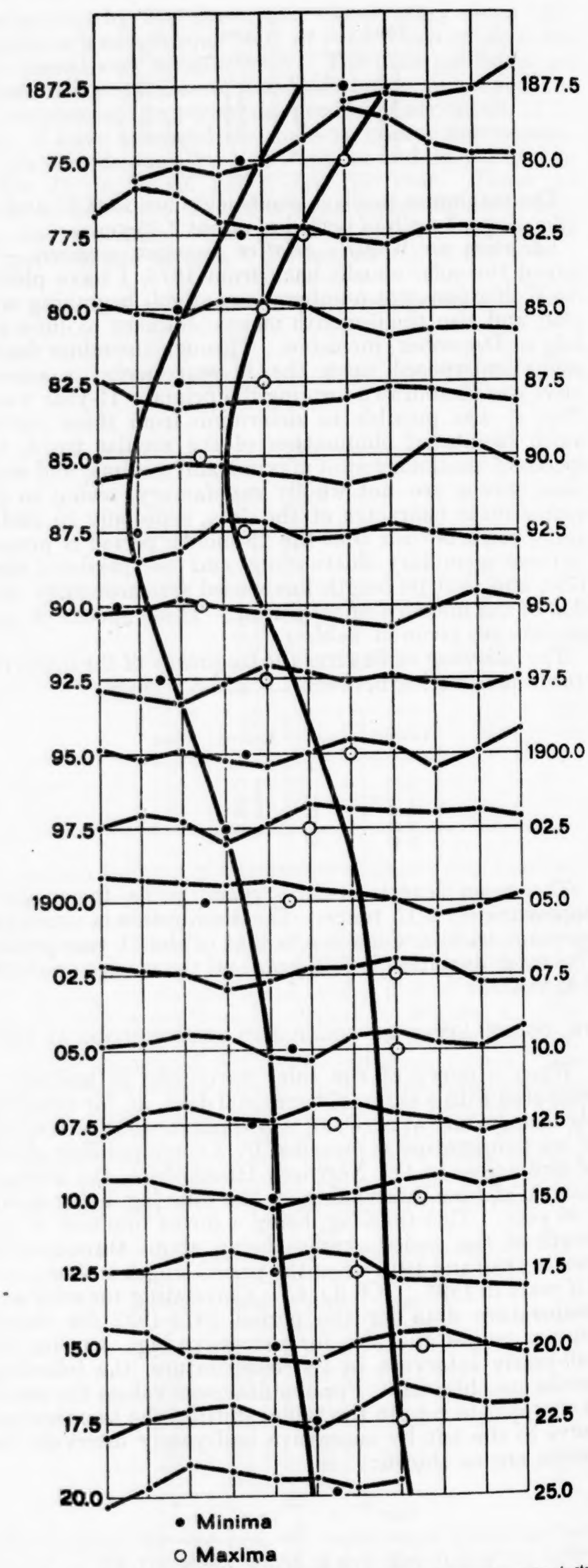


FIG. 5.—Graphical periodicity tabulation of combined temperatures for six stations in Minnesota, North Dakota, and Manitoba.

Figure 5 is a diagram of the composite curve of temperature from 1872. The deviations of the maximum and minimum phases on either side of the curve of best fit are, as stated above, partly due to the 11-year variation and partly due to other causes, among which are certain uneliminated short-period and accidental features of the data.

IX. CONCLUSION

The object of the investigation has been, as previously stated, the determination of the epochs of maxima and minima of the short period for restricted areas, and the systematic variations in its length. This has been accomplished satisfactorily by consideration of data for temperature and pressure in Europe and the United States only, where long homogeneous records are available.

The variations of rainfall have been given only secondary and partial consideration, since examination of data from the relatively few stations from which the epochs of temperature and pressure were derived have led to indefinite results for rainfall, owing to the local and fortuitous features of this element. Records from a large number of stations must be averaged to yield satisfactory results.

Large regions of the globe including Africa, Asia, and most of the Southern Hemisphere have been left for future work. The regions adjacent to the eastern Indian Ocean, including Australia, have been studied rather intensively so that the epochs for this section, well represented by Batavia, can be said to be definitively established.

The amplitude of the period has not been studied to any extent, since its exact determination is a complicated process which must be left for future development. From inspection of the curves certain qualitative conclusions may be drawn. It is probable that the amplitude varies directly with the wave length, as illustrated by the amplitude of the temperature wave at Portland (Section V); also that the amplitude is smaller than that of variations of longer period, as the 7-year period.

Regarding the correlation found to exist between solar and meteorological data, the paper presents simply the findings of the investigation without adequate physical reason for such relationship, which appears to be of a causal nature. In this, as in many other cases, theory must wait upon observation and there is much to be done before a satisfactory basis for induction can be said to exist.

DISCUSSION

By CHARLES F. MARVIN

Convinced of the great importance of serious and searching investigations of solar and terrestrial correlations and of the laws of sequence of weather conditions, the writer has encouraged and supported such work at the central office of the Weather Bureau to the fullest extent permitted by the limited personnel and funds available.

While the present paper represents the results of only a recent investigation, nevertheless these matters have been a subject of unofficial work and study by Mr. Clough for fully 20 years, all of which constitutes a substantial foundation and background for the present contribution.

Unwilling to publish in the MONTHLY WEATHER REVIEW a paper on the illusive question of periodicities by a member of our staff which could not command the approval, at least in general and tentative terms, of myself and others, this paper has received more than the usual critical examination, both by the committee on scientific papers and myself, with the result that it is believed Mr. Clough supports his findings by a substantial array of proofs derived directly from (1) a large and acceptable body of meteorological data, (2) reference to a series of seemingly incontrovertible statistical criteria, and (3) solar and terrestrial correlation of material significance. The study has been purely an inductive one and wholly lacks suggestions as to the physical causation of the findings. The task of the critic, therefore, is, of course, to successfully refute the argument, to interpret the evidence in other terms, and to show that the findings as a whole or in part are not the facts they are represented to be. If disproofs are not forthcoming in adequate form, we must conclude that Mr. Clough's views constitute an important contribution to the laws of sequence of weather conditions.

Unfortunately, readers but partly acquainted with the literature and the technique of the subject of weather periodicities will probably find it difficult to pick out the essence of Mr. Clough's findings from the mass of details which he has deemed it necessary to present in order to meet and forestall probable criticism and exceptions.

His claims are:

(1) The sun-spot cycle is a prototype of other solar and terrestrial periodicities, many of them being obscure and unknown.

(2) The seemingly erratic and irregular changes in lengths of such of these periods as some recognize, are due only in part to accidental causes, errors of determination, etc. In addition, some as yet unknown but dominant physical influences cause the lengths to change in a systematic manner.

(3) That there is a rhythmic response and a corresponding correlation between solar and terrestrial periodic phenomena.

Assuming that we have fairly stated Mr. Clough's major findings, let us examine critically some of the evidence and proofs thereof.

Raw material and smoothing formula.—With very few exceptions, the statistical data employed were in the form of 6-month means smoothed by the formula $(a+b)\div 2$, which gives a result exactly the same as 12-month means taken at 6-month intervals. While the amount of the smoothing in this case is very slight, nevertheless it must be recognized that the application of any smoothing formula to a sequence of numbers *tends to create consecutive correlation where none previously existed.* Furthermore, where obscure correlation of a periodic character already exists the smoothing tends to reduce or efface the amplitude and to shift or alter in a more or less unassignable way important phase relations.

Suppose a, b, c, d, e, f, etc., represent an irregular sequence of perfectly unrelated numbers. Let this sequence be smoothed by any such formula as, say $(a+2b+c)\div 4$, etc. There is at once created an implied relation of an obscure character between each derived value and those immediately contiguous thereto.

These considerations apply to all such results as are represented by the curves in Figures 1 and 2 of Mr. Clough's paper. However, the practice of using smoothing formulæ in cases of this character is all but universal, and Mr. Clough's use of them seems to be as fair and conscientious as that of any other investigator. Accordingly, we find no adequate ground for the rejection as a whole of the dates of maximum and minimum phases

which he has conscientiously picked out and listed in his Table 1. About the only fair criticism which can be made of these results is that they may be accepted on a qualitative basis, but can hardly be regarded as quantitatively exact. In the first place, the method leads to practically no exact information at all as to the amplitude of the wave forms, and the time units are too large to give sufficiently accurate values.

Time units too large.—Phase values at intervals of 6 months give, on the average, only 4 to 5 points per individual wave form. This would be quite sufficient for a well-defined symmetrical wave of uniform length and amplitude, but such an interval is quite too great to develop accurately the characteristics of this obscure, complex, and widely fluctuating 28-month period, as Mr. Clough describes it. Even his smaller estimated half-unit intervals help but little, as will more fully appear in what follows.

Changes in length of period are systematic.—Many investigators have recognized that the sun-spot cycle exhibits large and seemingly erratic changes in its length. For many years Mr. Clough has insisted that these and like changes in other periods are systematic. It is now proposed to critically analyze this claim for just a single portion of the data given in his Table 1, namely, the 61 intervals or wave lengths for temperatures in the United States, using the dates for minima only. These values are found to be fairly similar to the composite data shown in Mr. Clough's Figure 3 for the maxima and minima combined. The shortest length of period is 1.50 years, the longest 3.25 years.

Referring to Figure 6 it is easy to see how the entire 61 values in Table 1 can be represented by the simple numbers 1, 2, 3, ... 8, which for further purposes have been inscribed on 61 small cardboard disks, as suggested in the illustration. The small numbers beneath indicate the frequency of each disk. The marked irregularity, skewness, etc., of the frequency distribution of these 61 numbers is clearly apparent in the little diagram at the left, with its Gaussian curve of best fit. The following constants apply to the distribution:

Average length = 4.31 units = 2.33 years.

Mean deviation = md = 1.33 units = 3.32 years.

Standard deviation = $\sigma = \pm 1.71$ units = ± 4.28 years.

Cornu's ratio, $\sigma \div \mathrm{md} = 1.29$, should be 1.25 for Gaussian numbers.

The frequency of the length 5 (2.5 years) is much too high, compared with that of the other lengths. Coarseness of time unit must have a good deal to do with such an irregularity, but random sampling and the smallness of the total number of cases (61) must not be overlooked. Since we are supposed to be dealing with a quasi-periodic function we should notice that the frequency distribution of a table of natural sines is diametrically opposite to that of Gaussian numbers. That is, sines show a U-shaped distribution in which large departures from the mean are most numerous and small departures infrequent, with a Cornu ratio about 1.11. When its value is nearly 1.25 (or the reciprocal thereof, 0.80) Mr. Clough cites and uses the Cornu ratio as an index of conformity to Gaussian numbers. He regards the ratio 1.29 in the present example as indicating that the 61 numbers are normally distributed. Our own inferences are that the Cornu ratio alone is a very poor index of conformity or nonconformity to Gaussian numbers. Definite information of this character can be obtained only by setting up the actual distribution and plotting the Gaussian curve of best fit.

In the present example, the abnormally high frequencies 5 and 4, of the extreme lengths 1 and 8, is in itself evidence of ill-defined periodicity and as shown by a slight conformity to a sine distribution masked by disturbing conditions. The distribution of the 61 numbers in itself, therefore, carries a slight support of Mr. Clough's claim, but we have not examined other cases sufficiently to know whether this feature is general or not.

It is very important to recognize at this point that whatever physical influences have conspired to yield

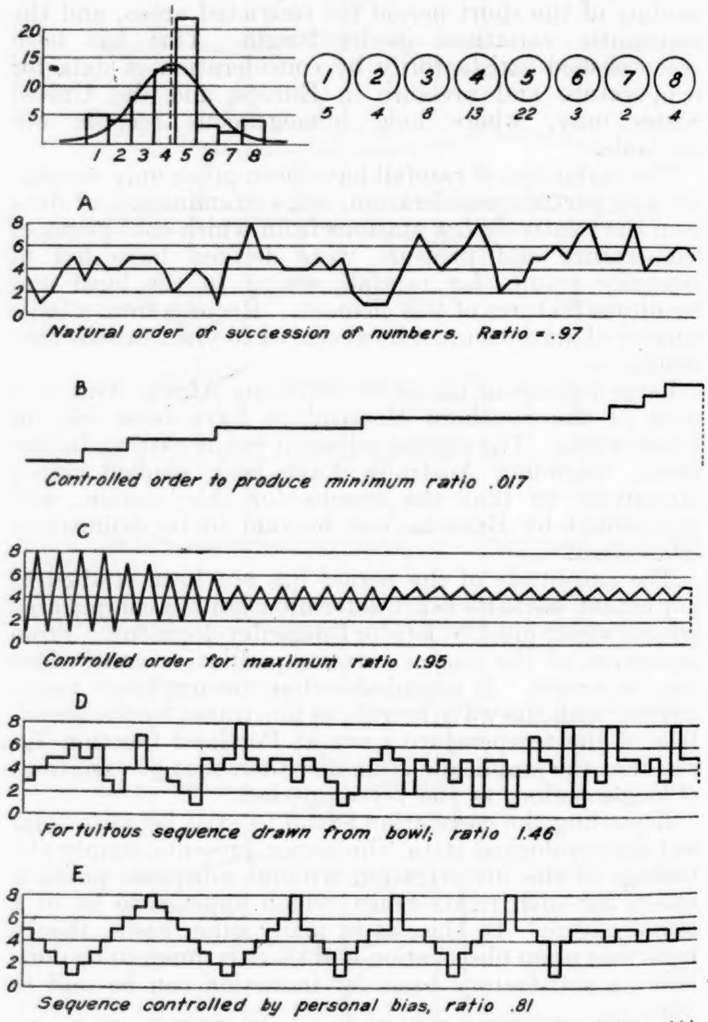


FIG. 6.—Diagram showing the frequency distribution of 61 numbered disks which represent the varying lengths of the 28-month period of temperature in the United States as measured from minimum to minimum. The natural order of succession of these lengths (graph A) is regarded as controlled because of the smallness of the Goutereau ratio, 0.97, whereas the ratio for a fortuitous sequence (graph D), by theory should be nearly 1.41. Graphs B and C represent sequences designed by personal intention to produce the minimum and maximum values of the ratio. Graph E is a sequence of the same numbers designed to have a periodic character resulting in a small value of the ratio, 0.81.

these 61 numbers possessing the statistical characteristics shown by the frequency diagram and numerical data just given, *the order of succession* has nothing to do with any of the above values. The numbers in their natural order satisfy the above distribution, but it is well known from the arithmetic of permutations that there are all but an infinite number of other orders of succession than the natural one, all of which likewise satisfy the same distribution. Mr. Clough maintains that the length of this period varies systematically; that is, there is something which makes the natural order of succession different from any other order that just happens by chance, in which case the variations in length must be regarded

as accidental. One of his proofs of this claim is that a certain statistical index, which may appropriately be called Goutereau's ratio,[28] has the small value of 0.97 for the numbers in their natural order of succession, whereas theory shows this ratio should have the value $\sqrt{2}$ or 1.41 for a wholly unrelated sequence of the numbers.

This is a very important point, and in order that each reader may understand and appreciate the full force of this argument we shall carefully define what Goutereau's ratio is. Every one knows that the algebraic sum of the *departures* of any group of numbers whatever from the *mean* or *average* is zero. The sum of all the departures *regardless of sign* divided by the number gives the *average departure* or *mean deviation*, a statistical index which is, like the mean itself, wholly independent of the order of succession.

Now to base any claim or argument upon a particular order of succession of a given set of numbers we must have a suitable measure or statistical index, depending upon the order of succession alone. Happily this index is the *mean variation, v.* In any irregular sequence of numbers a, b, c, d,....x, form the consecutive differences b–a, c–b, d–c...... a–x.[29]

As in the case of the departures from the mean, we find that the *algebraic* sum of all the variate differences, if taken in a ring, is zero. The sum *regardless of sign* divided by the number of values is the *mean variation*, which is the index for the order of succession we desire, and resembles and may be compared with the unchanging index afforded by the *mean deviation* of the same numbers regardless of order of succession.

Goutereau, with the aid of Maillet, has shown that the ratio $v \div md = 1.41$ for Gaussian numbers in fortuitous order of succession. Thus we have a very valuable index which closely relates the order of succession to the mean deviation of the same numbers.

With this explanation of Goutereau's ratio, each reader should easily appreciate the significance of what follows.

Referring again to Figure 6 the natural order of the 61 numbers with its ratio of 0.97 appears at A. From arithmetic we find there are more than 21×10^{11} possible different sequences. Two of these, arbitrarily set up to show the minimum and maximum Goutereau ratios, are shown at B and C. The 61 numbered disks were placed in a small bowl and from 10 separate drawings 10 values of the Goutereau ratio were computed, yielding an average value of 1.36. The lowest value was 1.24, the highest 1.51. One sample drawing is shown at D. The smallness of the value 1.36 as compared with 1.41 may or may not be significant. It seems that 10 drawings should be expected to give an average value of the ratio very close to 1.41, but it is probable in the present case that the original 61 numbers depart sufficiently from a Gaussian distribution to explain the relative smallness of the average of the 10 drawings.

The graph at E shows one result of personal control and bias in intentionally setting up a periodic sequence as far as the numbers themselves permit, giving the low ratio 0.81.

It seems utterly improbable that any fortuitous sequence could give the natural order of succession with its low ratio 0.97 any more than chance drawings could produce the selected orders of succession B and C, giving respectively the minimum and the maximum values of the ratio, or even the sequence E with its ratio 0.81.

The claim that the natural sequence of the numbers is a controlled sequence and not an accidental one can not be brushed aside either because a physical explanation of the control is wanting or without refuting or offering some better interpretation of the evidence than the foregoing, which deals with but a fragment of the whole body of data, correlations, etc., submitted by Mr Clough.

To conclude this brief note, we must recognize that in its present form we are undoubtedly dealing with a very complex feature of periodicity, probably made up of two or several elemental forms. It is well known that two periods differing slightly in length, one with large amplitude and the other with small, yield a composite period which appears to change its length systematically. Quite an extended examination on my part of data by the Fourier analysis gives little hope of explaining the observed facts in that way. A large number of elemental periods always appear to be necessary to even approximately represent the observations. Nevertheless, the subject has by no means been adequately investigated and is entitled to the serious attention of students and critics alike.

[28] See footnote no. 14, ante.

[29] By including the last term (a–x) we literally assume that the numbers constitute a closed system as if in a ring. This also causes the number of variate differences to be the same as the number of values, also the same as the number of departures from the mean. If the difference a–x is *not* included, the number of variate differences will be n-1 for n observations, and other technical inconsistencies arise which become inconsequential, however, when n is very large, which, on the other hand, is seldom the case. Therefore, we prefer to analyze all these cases as if the observations constituted a closed ring or system.

VAN BEMMELEN ON THE INTRATROPICAL PART OF THE GENERAL CIRCULATION OF THE ATMOSPHERE

By B. M. VARNEY

(Weather Bureau, Washington, September 25, 1924)

Dr. W. van Bemmelen in a recent paper in the Meteorologische Zeitschrift[1] makes one of the most import contributions to the study of the general circulation of the atmosphere that has appeared in recent years. During the years 1909–1917 at Batavia a total of 869 pilot-balloon flights were carried out, most of them being observed by double theodolite.[2] Doctor van Bemmelen has previously discussed the Batavia observations and offered tentative explanations for the phenomena observed.[3] His paper here summarized extends and somewhat revises his former views. Correlated with the results of the balloon flights as the basis for his discussion is evidence as to the intratropical circulation deduced from cirrus movements in the region.

Method of summarizing the data.—The author takes care to point out that the paucity of observations from the higher levels renders interpretation of the conditions there somewhat doubtful, and then states his method as follows:

> For each level and each month the north and east components of all observed wind vectors were combined and the means computed. With the aid of these means two isopleth diagrams were constructed, one for the north component and the other for the east, using altitudes as ordinates and months as abscissæ and from them the mean directions and velocities were computed. Such procedure is obviously justified where constancy of direction of the air streams is a notable feature.

For the purposes of this note, the writer has translated the results of the above procedure from van Bem-

[1] Volume 41, 1924, no. 5, pp. 133–141.

[2] Results of the observations are dealt with in Transaction Nos. 1 and 6 of the observatory.

[3] Proc. R. Acad. of Sciences, Amsterdam, Apr. 26, 1918. A paper by W. van Bemmelen and J. Boerema, "Horizontal oscillation of the free atmosphere up to 10 km. at Batavia," published in Proc. K. Akad. Amsterdam, 1917, vol. 20, pp. 119–135, was abstracted in Science Abstracts, Sec. A, Nov. 30, 1917, No. 1235, this abstract being reprinted in the MONTHLY WEATHER REVIEW, January, 1918, **46**: 22. See also van Bemmelen, W., "The antitrades," MONTHLY WEATHER REVIEW, 1922, **50**: 90–91, reprinted from Nature, Feb. 9, 1922, pp. 172–173, and brief discussion of this paper by Shaw, W. N. in same REVIEW, p. 92, reprinted from Nature, Feb. 16, 1922.

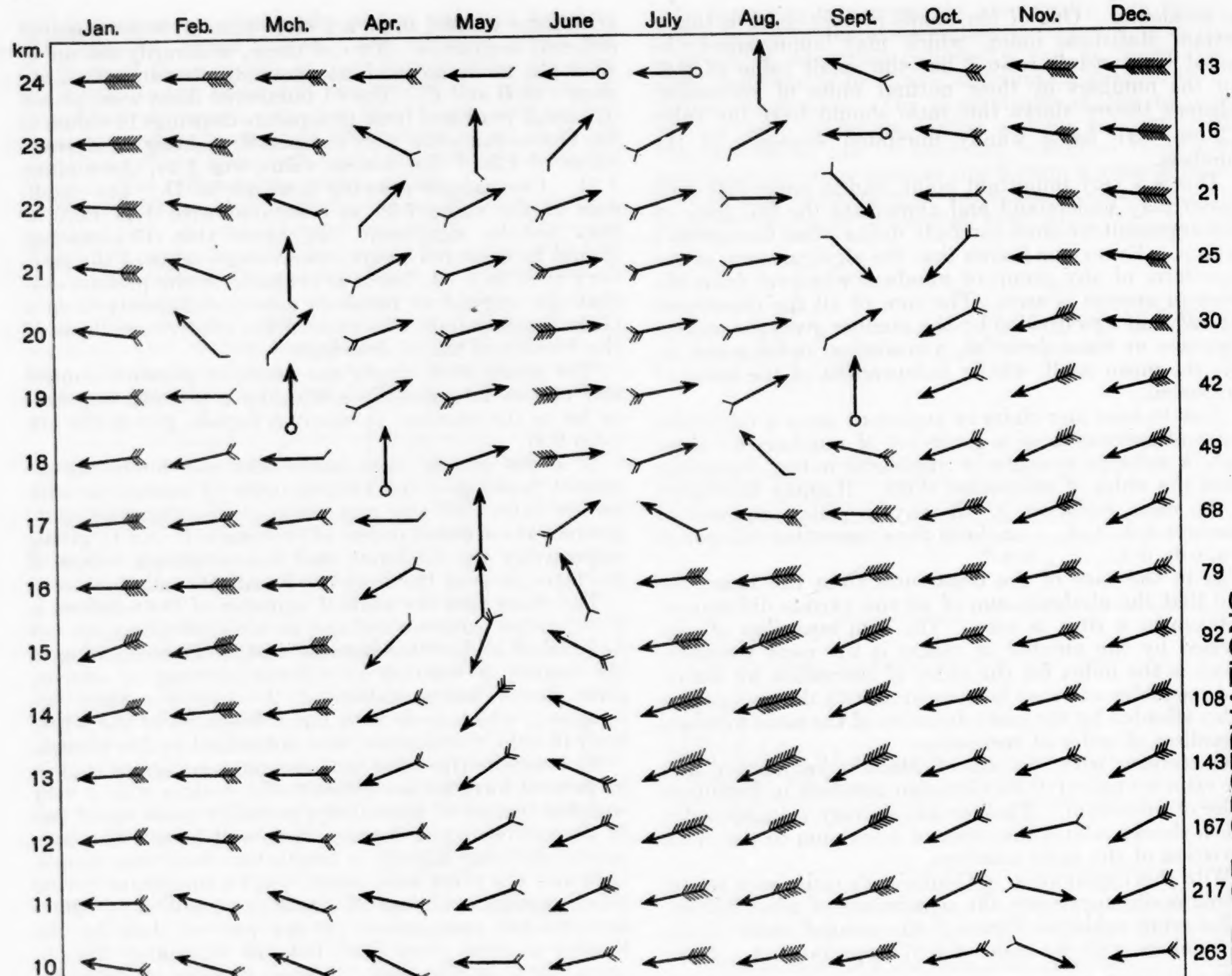


FIG. 1.—Mean wind directions and velocities over western Java, based on van Bemmelen's Table 1 in Met. Zeit., May, 1924, p. 134. Arrows fly with the wind. Velocities in m. p. s., each feather equaling 1 m. p. s. At 10-km. altitude and below, tenths of a m. p. s. are approximately represented by the fractional lengths of a feather

melen's table into graphic form (fig. 1) that the great seasonal shifts of the air streams over western Java may be more clearly visualized and a comparison made easy with his map showing conditions at the cirrus level.[4] In this figure, north being at the top and east at the right, the arrows fly with the wind, and mean velocities in meters per second are shown by the number of feathers (a feather to each m/s) on the arrows. Below 10-km. altitude, velocities were carried out to tenths of a meter per second, and these tenths have been approximated in the fractional lengths of a feather.

Several major air streams are distinguished:

1. At the earth's surface the west monsoon from November to April.
2. At the earth's surface the east monsoon during the rest of the year.
3. Above these streams, a current from points between east and southeast, persisting throughout the year, and designated as the trade wind.
4. Above the trade, a deep current flowing from points largely between east and northeast, persisting throughout the year, to which the name pseudoantitrade is provisionally applied.
5. Above this antitrade a reversion to winds from directions south of east at certain altitudes and times of year, the upper trade wind.
6. At the upper limit of observation an east wind, persisting through nine months of the year, though of high velocity for only about half the year, designated as the Krakatoa wind.
7. Above the antitrade also, during a part of the year, a west wind with components of motion from the south, called the high-altitude west wind.

Before summarizing Doctor van Bemmelen's discussion and explanations of the different currents, attention may be directed to Figure 2, in which for five representative levels the annual march of wind velocities has been plotted. By varying the characters of the lines it has been possible also to show every important change in the régime of the winds, except for the east monsoon, which will be seen presently to be but a local manifestation of a much more important stream, and excepting also the base of the west monsoon, the main flow of which is better represented by conditions in the 2-km. level. Brief note may be made of the following points:

The 2-km. level.—Alternation of west monsoon and the southeast trade, the trade riding above the monsoon (see curve for the 10-km. level) from November to April, inclusive, but descending into the same level as the west monsoon during the Southern Hemisphere winter.

The 10-km. level.—Alternation of the trades (January to April, inclusive) with the antitrades (May to December, but interrupted in November by the unexplained westerly winds).

The 15-km. level.—Continuous antitrade throughout the year except in June, when it is changed into a wind from the east of south. This change is apparently due to friction with the overlying high-altitude west wind, since the same type of change occurs also in the 16, 17, and 18 km. levels during May to September. It will be noticed that the depth to which the influence of the west wind penetrates changes simultaneously with the changes of altitudes of the bottom of the west wind.

The 20-km. level.—Three great streams at different times of the year occupy this level. The basal portion of the upper trade descends to it during January-February; the heart of the high-altitude west wind at its greatest velocities is found here from March to September, inclusive, and with the dying out of this wind it is replaced during October and November by the antitrade, which in those months reaches its maximum altitude (21 km. plus in October). In December, the east wind at this level appears to be merely the mean effect of the antitrade below and the upper trade above, and it soon gives way to the upper trade, which is seen continuously to extend the depth of its influence through the period September to January, inclusive.

The 24-km. level.—Three currents also in this level: the Krakatoa wind for eight months, an unsettled condi-

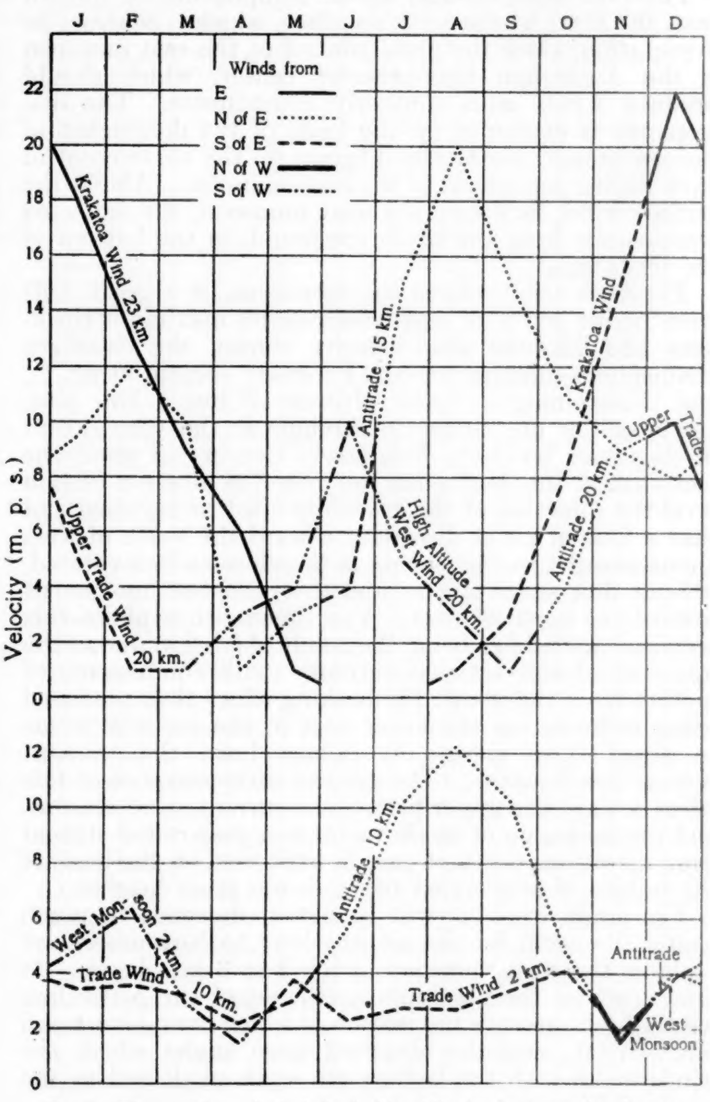


FIG. 2.—The annual march of wind velocities at five levels over western Java

tion in August, and the upper trade wind in September, October, and November. The Krakatoa wind is seen in June and July to be largely neutralized by the high-altitude west wind.

Comparison of Figures 1 and 2 emphasizes the fact that the seasonal changes of altitude of the different streams is so great that at no single level does the same wind blow throughout the year. Perhaps the most striking result of these changes is seen in April and May, when at many levels the transition from one régime to another takes place, and wind velocities consequently are in general relatively low and direction variable. This slackening of activity obviously corresponds with the reversal of the monsoon occurring in the lower 3 km. in those months.

[4] Reproduced from the MONTHLY WEATHER REVIEW.

DETAILS OF THE VARIOUS WINDS, WITH EXPLANATIONS SUGGESTED BY VAN BEMMELEN

The west monsoon shows components of motion from the north at the earth's surface, but from the south above 1 km. It is controlled by the Australian low-pressure center, the isobars of which over western Java trend about SW.-NE. Friction at the earth's surface determines the direction from north of west across the isobars, but relative lack of friction aloft allows air movement there more nearly parallel to the isobars, with the result that the air flows from points somewhat south of west.

The east monsoon also shows components of motion from the north at the earth's surface, which is contrary to expectation, since the great control of the east monsoon is the Australian high-pressure center, which should produce winds with southerly components. The discrepancy is explained on the basis of the dominance of the sea breeze over the land breeze on the north coast of Java during the season of the east monsoon. Above the surface wind, as above the west monsoon, the expected components from the south are found, in the bottom of the trade wind.

The trade wind, above the monsoons, is a great drift from points south of east, reaching its maximum thickness and altitude and velocity during the Southern Hemisphere summer (see the February column in fig. 1), and maintaining a winter altitude of but 3 km. plus. Its velocities are moderate throughout the year except in its upper levels in February. Bearing in mind the fact that in the Australian low pressure above a certain level the direction of the gradients must be reversed and that a flow of air in directions toward the south of west about parallel to the isobars is therefore to be expected, it is at first surprising to find the persistent movement toward the north of west. Van Bemmelen explains this seeming anomaly as being the result of friction due to the upthrust of convectional currents (with components of motion from the west), the braking effect thus produced being sufficient in the lower part of the easterly winds to direct them across the isobars down the gradient toward the Equator. The gradual disappearance of this effect toward the upper part of the current at all seasons, and the taking on of its character as a year-round current from directions north of east, is explained on the basis of the failure of convection to reach the great heights.

The trade wind, it will be noted, descends to much nearer the earth for the months May to November, and replaces the west monsoon in the 2 to 3 km. levels. It now flows on the gradients northwest of the Australian winter high pressure the isobars of which over Java trend ENE–WSW, and the observed large angles which the winds make with the isobars are again explained as the result of friction.

The antitrade (or pseudoantitrade) comes next above the trade, and flows throughout the year (except in June at 13 to 16 km.) as a deep and for the most part swift stream from directions north of east, a nearly frictionless motion parallel to the isobars, these being in one half year the isobars of the upper portion of the Australian cyclone and in the other half those of the Australian anticyclone. Over Java both systems trend about ENE–WSW. The name pseudoantitrade is provisionally applied to this wind because of uncertainty as to whether it really is a part of a great poleward outflow or merely the local manifestation of the high-altitude equatorial air stream. This point will be referred to presently.

The upper trade wind, not quite so strikingly shown in the diagram as those hitherto noted, nevertheless can be traced as a flow from the east with distinct components from the south. From October to February it occupies the very high levels (18 to 22 km.) and in the opposite half year much lower levels, reaching in June the 13-km. level. Its velocity decreases, broadly speaking, as its southerly components increase, or toward the bottom of the flow. In its upper portion it is seen to merge gradually, in respect to both velocity and direction, into the east wind at the upper limit of observation.

This upper trade wind represents a reversion to air movement from the south of east, as already noted for the case of the trade wind. Friction is assigned as the cause. It will be seen that in the months May to September a high-altitude west wind blows, a deep stream in contact both above and below with air moving from easterly directions. To the drag thus caused is assigned the failure of the easterly winds to flow parallel to the assumed trend of the isobars (from N. of E. to S. of W.) in those levels.

The Krakatoa wind has been referred to above, indirectly. It is regarded as a wind distinct from the upper trade. It constitutes the highest flow observed, is persistent except in June, July, and August when the high-altitude west wind, reaching its greatest height, disturbs the base of the Krakatoa current, which maintains a high velocity except in those months when it seems to be affected by friction with the high-altitude west wind, May to September. The name of this highest stream is assigned because of its correspondence in altitude, direction, and velocity with the observed travel of the Krakatoa dust. The similarity in velocity is not shown in the diagram, hence it is of interest to note that in two cases the Batavia flights reached the 30-km. level and showed high velocities to exist there, as follows:

Sept. 12, 1912:
29.5 km., 40.4 m/s.
30.5 km., 34.3 m/s.
Mar. 2, 1913:
29.0 km., 47.4 m/s.
30.0 km., 43.1 m/s.

The high altitude west wind, with distinct components from the south, shows only moderate speed except at 18 to 20 km. in June, when it averages 10 m/s. Its *raison d'etre* is very difficult to assign. The suggestion is advanced that it seems to be connected with the great west-to-east circulation of the Southern Hemisphere, since it displaces the easterly flow over Batavia in those months when the circumpolar whirl of the Southern Hemisphere spreads northward—in other words, it waxes and wanes with the migration of the sun. The conception thus is, that during the Southern Hemisphere's winter the rotating disk of air which is felt at the earth's surface in the Roaring Forties and southward, to the north may overspread the tropical high pressures aloft and extend its wedge into the high altitudes at least as far north as Java. An evident difficulty with this interpretation is recognized in the southerly components shown by this wind, which indicates that in those altitudes in those months at least locally the gradients slope toward the Equator—not away from it, as would be necessary to cause the poleward flow of air demanded by the indraft of the trades at the earth's surface. This point will be touched upon again.

We now turn to the substance of van Bemmelen's discussion concerning the relations of the air streams described above to the general intratropical circulation. The discussion is mainly centered upon the significance of the equatorward components of motion in the upper trade and the high-altitude west winds, and of the poleward components in the current of the antitrade.

Van Everdingen has maintained [5] that a poleward outflow must take place at a much higher altitude than

[5] Tijdschrift K. Aardrijkskundig. Gen. Amsterdam, 1918 and 1919.

those occupied by the antitrade, say at 20 to 30 km. The Batavia observations show, however, at 20 to 23 km. for the Southern Hemisphere summer a distinct component from the south of east—an inflow. In the opposite season, the high-altitude west winds at these heights show still more marked southerly components. Moreover, a major objection to supposing that an important poleward flow exists at great altitudes lies in the relative densities of the air at these and at lower levels, and the consequent inability of such a flow to accomplish the poleward displacement of enough air to drain away the much denser indraft occurring in the lower levels. (See Table 1.)

Furthermore, the view that because of the earth's rotation the inflow of the trades becomes the outflow of the antitrades *in a continuous belt round the globe* connotes a grotesque isobaric system. For, at the altitude of the antitrade, motion is necessarily very close to the isobars. Hence on the assumption of a continuous belt of antitrades, pressures in the equatorial belt would have to decline endlessly toward the west—an impossible condition.

Van Everdingen [6] and Shaw [7] arrive at the conclusion that the belts of high and of low pressure aloft are not continuous, but break up into centers strung along their general axes. Shaw, by computation for the 8-km. level in the Northern Hemisphere finds high pressure centers at about 20° N. latitude over Central America, northern Africa and southern Asia, and on the basis of the necessarily resulting anticyclonic winds infers the transfer of air from the equatorial east wind into the antitrade "as through a gear drive." Van Bemmelen, pointing out that the equatorial cirrus level lies close below the level of maximum poleward displacement of air over western Java (see Table 1) assembles data on the average stream lines of equatorial and intratropical cirrus as shown below in the maps for the half years (fig. 3). These average flows, though unavoidably based on fragmentary data (Table 2), are those which would result from Shaw's computed pressure system for the 8-km. level, and suggest that similar high-pressure centers aloft exist south of the Equator also.

TABLE 1.—*Relative displacements of air in layers 1 km. thick up to 24 km., by months.* (Van Bemmelen)

The heavy line separates winds with easterly components from winds with westerly, and the broken line northerly components from southerly.

(Relative displacements = 10 × wind velocity in m/s × density of the air)

Km.	J	F	M	A	M	J	J	A	S	O	N	D
24	7	5	3	2	0	0	0	0	1	3	6	8
23	7	4	3	1	0	0	1	0	0	2	4	7
22	6	4	2	1	1	2	2	1	1	2	5	9
21	6	2	1	1	2	3	3	2	1	2	6	8
20	4	1	1	2	3	8	4	2	1	3	7	8
19	5	2	0	2	5	9	5	2	0	5	9	9
18	7	4	1	0	3	11	3	1	6	7	10	10
17	13	10	7	1	3	6	3	11	14	13	14	10
16	18	18	8	3	3	3	18	22	21	18	14	13
15	17	22	18	2	5	7	27	36	27	20	16	14
14	18	22	18	8	12	10	34	44	28	18	16	18
13	20	23	18	10	10	13	43	45	33	15	15	20
12	16	18	13	10	8	13	39	44	31	13	5	16
11	14	12	9	9	9	18	36	39	33	15	6	12
10	12	12	11	7	10	19	34	41	34	16	5	13
9	11	13	11	7	14	20	34	37	33	19	4	11
8	12	13	11	6	17	22	32	34	30	22	2	12
7	7	9	7	5	17	22	32	32	27	22	2	9
6	7	4	0	3	16	24	22	24	22	21	8	7
5	13	11	6	3	17	20	19	14	14	19	14	6
4	20	20	10	6	18	16	14	16	9	21	16	7
3	30	36	16	7	22	13	12	8	15	31	17	13
2	37	47	22	11	29	17	20	20	26	31	14	29
1	37	55	25	8	24	22	28	33	34	24	14	32
0.1	22	23	13	8	5	12	14	12	14	22	17	17

TABLE 2.—*Average stream lines of Cirrus clouds.* (Van Bemmelen

[---------no data]

Station	Latitude	Longitude	Motion from: Winter	Summer	Year
Samoa	-13.5°	172° W.	W. 9° N, Dec.-Feb.	W. 33° N. June-Aug	S.
Hawaii	19	155	----------	----------	W.
Mexico	19-33	100	W. 57° S. Dec.-Feb.	E. 36° N. June-Aug.	
San Jose	10	84	E. 3° N. Dec.-Feb.	E. 10° N. June-Aug.	
Habana	23	83	W. 15° S. Dec.-Feb.	E. 26° N. June-Aug.	
Washington	39	76	N. 79° W. Oct.-Mar	N. 77° W. Apr.-Sept.	
Lesser Antilles	14	62	E. 7° S. Dec.-Feb.	E. 30° S. June-Aug.	
Paramaribo	6	55	E. Dec.-Feb.	E. 2° S. June-Aug.	
Atlantic Ocean	25-30	30	----------	SW. Apr.-Sept.	
Fayal	39	29	WSW. Winter	NW. Summer	
Square 3	0-10	20-30	E. 51° S. Dec.-Feb.	E. 12° N. June-Aug.	
Square 39	10-12	20-30	W. 46° S. Dec.-Feb.	E. 17° S.	
Cape Verde	15	25	----------	SE. Summer	
Ascension	-14	8	----------	----------	NE.
San Fernando	36.5	6.5	W. 30° N Dec.-Feb.	W. 1° S. June-Aug.	
Congo	-5	14 E.	----------	----------	E. 37° S
Johannesburg	-27	28	Dec.-Feb	W. 8° S. July-Sept.	
Mauritius	-20	57	N. 80° W. Dec.-Feb.	N. 39° W. June-Aug.	
	16-21	----------	N. 67° W. Dec.-Feb.	S. 59° E. June-Aug.	
	12-16	----------	N. 33° E. Dec.-Feb.	N. 65° E. June-Aug.	
Arabian Sea	8-12	65	N. 82° E. Dec.-Feb.	S. 54° W. June-Aug.	
	4-8	----------	N. 58° E. Dec.-Feb.	S. 39° W. June-Aug.	
	0-4	----------	N. 34° E. Dec.-Feb.	S. 82° W. June-Aug.	
Madras	13	80	S. 13° W. Nov.-May	E. 8° S. June-Oct.	
Allahabad	25.5	82	S. 86° W. Jan.-Mar.	E. 27° N. July-Sept.	
Vizagapatam	18	83	S. 4° W. Nov.-May.	E. 18° N. June-Oct.	
Calcutta	22.5	88	S. 84° W. Jan.-Mar.	S. 14° E. July-Sept.	
Batavia	-6	107	E. 1° N. Dec.-Feb.	E. 25° N. June-Aug.	
Pontianak	0	109	E. 5° S. Dec.-Feb.	E. 27° N. July-Sept.	
Manila	15	121	E. 66° S. Dec.-Feb.	E. 12° N. June-Aug.	
Zikawei	31.5	121	W. 1° S. Dec.-Feb.	W. 45° N. June-Aug.	

Sources: Batavia and Pontianak: Proc. R. Acad. Amsterd., Apr. 26. Samoa: G. Angenheister in Nachr. Gött., 1909. Arabian Sea: Quart. Jour. Roy Met. Soc. 1893. India: Indian Met. Memoirs, IV, 8. Atlantic Ocean: W. Peppler in Beitrage zur Phys. d. fr. Atmos. Band. 4. Remaining observations from: Hildebrandson and Teisserenc de Bort, Les Basses de la Météorologie Dynamique, Nova Acta Upsala. Ser. 4, vol. 5, no. 1.

The indicated equatorward displacement of the high pressure centers at the cirrus level as compared with their positions at the earth's surface (it is seen to be of the order of 15°) coincides with the views of Teisserenc de Bort and of Exner.[8] W. Peppler finds for the Atlantic Ocean and for Africa that at 12° N. latitude the pressure at 10 km. is about 4 mm. higher than over the Equator. Hence at this level there still exists a belt of equatorial low pressure. The conception thus is that the trade wind air rising from the earth's surface gets into the anticyclonic circulations, and flows thence, locally on the appropriate sides of the high-pressure centers, into higher latitudes. Such a flow may well be the great antitrade stream found above Batavia. This assumption is supported by the consideration that the tropical high pressure centers, not yet extinguished at 10 km., may persist to much greater altitudes in all tropical regions where convection is the rule. Thus at Batavia this elevation would be some 17 km. Locally also, a part of this originally trade wind air must flow toward the contracting remnant of the equatorial low-pressure belt that is still to be found between the not yet completely merged high-pressure centers. The example of this over Batavia would be the upper trade wind, or pseudo upper trade, as van Bemmelen calls it. As between the inflows and outflows, the latter must greatly exceed the former, though the outflows are diminished by the amount of air that rises into still higher levels.

To these anticyclonic circulations in the cirrus level and above is assigned also the important function of furnishing the driving force for the great and swift stream of air which flows, in the highest altitudes to which observation extends, in a more or less meandering course from east to west along the Equator, as described by meteorologists from Ferrel onward. These rotations thus not only transfer air outward to feed the antitrade flows,

[6] Loc. cit.

[7] Nature, July 21, 1921.

[8] Loc. cit., p 177.

but inward to some extent also, thereby transferring to the so-called Krakatoa wind the energy of the inflowing air streams from higher latitudes. To apply the imagery of Shaw in this connection also, the tropical anticyclones in the high altitudes act as so many gear pumps for the operation of the high-altitude east-to-west current along the Equator. The competence of these gigantic pumps to perform the several functions assigned to them is indicated by van Bemmelen's table of displacements already referred to.

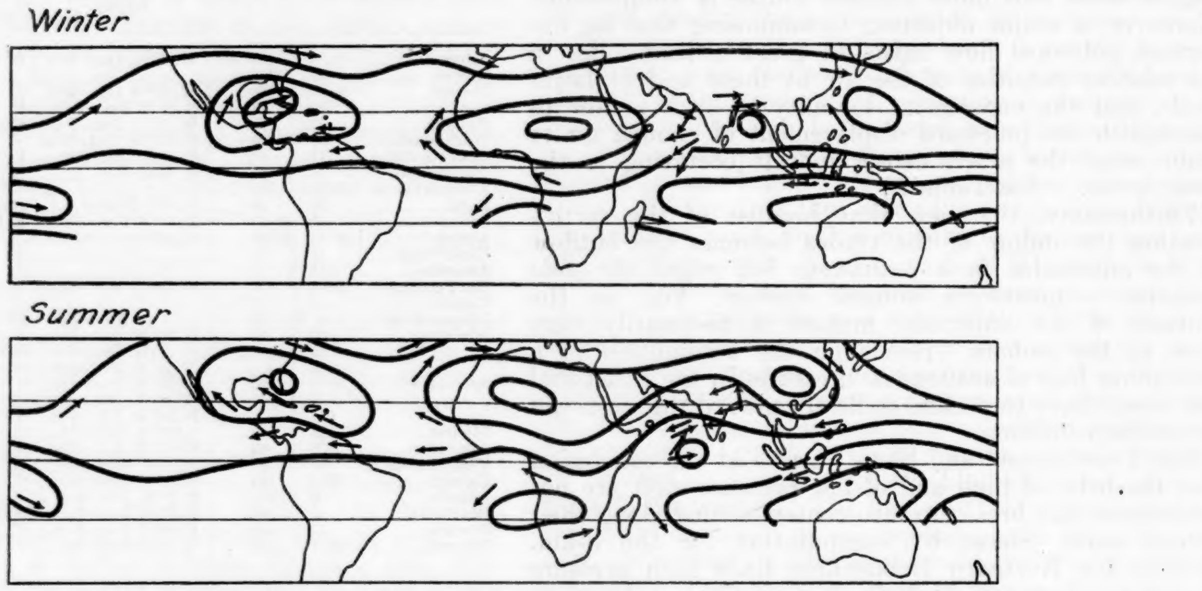


FIG. 3.—Lines of flow of cirrus drift. Reproduced from MO. WEATHER REV., February, 1922, p. 91. See Table 2 of the present paper for data

MITCHELL ON WEST INDIAN HURRICANES AND OTHER TROPICAL CYCLONES OF THE NORTH ATLANTIC OCEAN [1]—A REVIEW

By ALFRED J. HENRY

The publication under review is the third of the series of memoirs by Weather Bureau officials devoted exclusively to a study of tropical cyclones which at times invade the southeastern United States. It may be helpful at this time briefly to review the two earlier publications [2] and to refer to a Signal Service publication [3] containing the first official comment upon West Indian hurricanes put forth by the Federal weather service.

This publication, although based upon but 10 year's observations, brings out with remarkable clearness most of the essential facts with respect to the distribution and origin of West Indian hurricanes. The following statement with respect to their origin is significant: "An almost entire absence of reports from the region east of the Windward Islands prevents the tracing of storms to their place of origin."

Garriott's treatment of the subject in Bulletin H is descriptive and historical rather than theoretical, although he gives some space to the theorizing of others. His viewpoint is essentially that of the forecaster and he therefore treats the premonitory signs of the approach of a cyclone rather fully. The historical aspect is also fully considered even to reproducing Poey's list of hurricanes in the West Indies from 1493 to 1855. At least 60 per cent of the space in the bulletin is devoted to a description of individual storms, first by months and again without much regard to the chronological arrangement of the storms, and finally 27 quarto pages are devoted to local records and descriptions of hurricanes drawn from the archives preserved in the islands of both the Greater and the Lesser Antilles. The example he set is a difficult one to follow in these days of economy and high cost of printing; indeed, the utility of much of the word pictures of experiences in tropical cyclones may well be questioned.

The next memoir, that by Dr. O. L. Fassig, was issued in 1913. It discusses the occurrence of tropical cyclones from a statistical viewpoint, omitting lengthy descriptions of severe storms except in the single case of the August, 1899, storm, which passed directly across Porto Rico and was carefully observed at a number of points in the several quadrants of the cyclone. Both Garriott and Fassig depended for their paths of tropical storms upon the Forecast Division series of daily weather maps as constructed from reports received by telegraph and cable.

Mitchell's studies differ from those of his predecessors in that he replotted the paths of all tropical cyclones of which he could find evidence within the period 1886–1923, using in addition to the Forecast Division charts another series of charts, viz, those taken over from the Hydrographic Office of the Navy and later continued in the Marine Section of the Weather Bureau from mail reports of ships' observations in the North Atlantic and adjacent waters. He was thus able to plot a greater number of storms than did his predecessors, but the outstanding feature of his work was the extension of the paths of storms picked up in or near the Windward Islands far to the eastward, and thus he completely confirmed the opinions expressed by several writers thirty-odd years ago to the effect that the origin of August and September storms would be found in the vicinity of the Cape Verde Islands. Viñes especially gave the reasons why cyclones should develop in the vicinity of the Cape Verde Islands [4] in August and not in other months.

[1] Mitchell, Charles L., "West Indian hurricanes and other tropical cyclones of the North Atlantic Ocean." MO. WEATHER REV. SUPPLEMENT No. 24, Washington, 1924.
[2] Garriott, E. B., "West Indian hurricanes," W. B. Bull. H., Washington, 1900, and Fassig, O. L., "Hurricanes of the West Indies," W. B. Bull. X, Washington, 1913.
[3] Dunwoody, H. H. C., Summary of International Meteorological Observations, Washingtom, 1893.

[4] Viñes, Benito, S. J., "Investigations of the cyclonic circulation and translatory movement of West Indian hurricanes." W. B. No. 168, Washington, 1898, pp. 24–25.

Seventy-odd years ago W. C. Redfield, of New York, collected ships' observations made in connection with an intense tropical storm in the North Atlantic—that of August 30, 1853, and he was able to plot its track from near the Cape Verde Islands west-northwestward to the vicinity of Cape Hatteras where it recurved to the northeast and passing over Rockall Bank was lost in the neighborhood of the Faroes because of lack of ships' reports from that region.

This hurricane, called by Redfield the Cape Verde-Hatteras hurricane, was very definitely plotted for a distance of 7,200 miles; the lowest recorded barometer was 27.30 inches on September 3 in N. latitude 20°; W. longitude 56°, and on September 9 the diameter of the storm extended from Newfoundland to the Azores.[5]

Twenty years later the British Meteorological Office investigated the meteorological conditions that prevailed over the North Atlantic during August, 1873, and issued a very complete monograph as a result.[6] Doubtless the great majority of meteorologists are familiar with that report, but it would seem as if but few are aware of the earlier record of a similar hurricane by Redfield. Apparently no one sought to trace the paths of West Indian hurricanes back to their origin until Mitchell took up the task in late 1922. His chart of August tracks shows no less than 11 hurricanes having their origin in the immediate vicinity of the Cape Verde Islands. In the first half of September this number falls off almost one-half and in the second half of that month but a single storm is shown as developing in the region just mentioned.

The conclusion is also reached that there is a second place of origin of tropical storms of the North Atlantic, viz, the western third of the Caribbean Sea. Mitchell excludes the eastern two-thirds of that body of water as a place of origin of tropical storms. Early students, Viñes, particularly, were of opinion that the entire Caribbean is a region in which tropical storms develop. The ground for the later view is evidently the ships' observations which were not available to early investigators.

A second important conclusion is the definite statement that a tropical storm will recurve to the northward and northeastward at the first favorable opportunity, regardless of the season or the longitude of its position. That is to say, the pressure distribution of the North Atlantic, especially the Azores anticyclone, determines when and where the recurve will occur.

MONTHLY FREQUENCY

The various memoirs on hurricanes herein quoted make it possible to compare the monthly frequency of these storms as independently determined by the several authors. I have assembled the monthly frequencies in percentages of the whole number of storms and present the numbers in the table following:

[5] W. C. Redfield, "Cape Verde and Hatteras hurricane," Silliman's Journal, second series XVIII; 1-18.

[6] Meteorology of the North Atlantic during August, 1873, illustrating the hurricane of that month. London, 1878.

TABLE 1.—*Frequency of West Indian hurricanes (in per cent) by various authors*

Author	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Poëy [1]	1	2	3	2	1	3	12	17	23	19	5	2
Dunwoody [2]				2	0	2	5	28	25	30	3	5
Garriott [3]					1	3	3	26	26	34	3	3
Fassig [4]					1	6	4	25	32	30	1	0
Mitchell [5]					0	7	7	16	33	30	6	1

[1] 363 years, 1493-1855.
[1] 10 years, 1878-1887.
[3] 23 years, 1878-1900.
[4] 35 years, 1876-1910.
[5] 37 years, 1887-1923.

One must be struck with the rather remarkable uniformity in the frequencies for August, September, and October, with but two exceptions, viz, those of October by Poëy and August by Mitchell. Poëy's table may contain at least 10 per cent of extra-tropical cyclones since 5 per cent are reported as having occurred in the winter months alone.

CLASSIFICATION OF CYCLONES

Mitchell in common with other writers has taken into account all storms regardless of their intensity and his statistics should be interpreted accordingly. Fortunately he has given the number recorded in each of the three groups into which they were divided. These groups and the number in each are as follows:

Group No. 1.	Storms of known hurricane intensity (winds of at least 60 m. p. h.)	122, or 51 per cent.
Group No. 2.	Storms whose intensity is in doubt, because of an insufficient number of reports	57, or 24 per cent.
Group No. 3.	Storms known to have been of less than hurricane intensity	60, or 25 per cent.

The monthly distribution of all storms considered by Mitchell is found to be as follows, total number of storms plotted in each month:

May	1
June	16
July	17
August	39
September	78
October	71
November	15
December	2
Total	239

The SUPPLEMENT is illustrated by 9 charts of paths followed by the tropical storms of the North Atlantic and many weather charts (mostly isobars only) portraying the pressure distribution in typical severe storms in the several months of the hurricane season. The publication is not for general free distribution; copies may be had from the Superintendent of Documents, Washington, D. C. to whom remittances should be made. The price of the publication is 50 cents.

TORNADOES IN WISCONSIN,[1] SEPTEMBER 21, 1924

By W. P. STEWART, Associate Meteorologist

(Weather Bureau, Milwaukee, Wis., October, 1924)

On Sunday, September 21, 1924, a marked area of low pressure passed northeastward across Wisconsin, causing high winds throughout the State and destructive squalls and tornadoes over wide areas in many north-central and northern counties. There was more or less damage in all parts of the State. At Milwaukee, in the southeast, many trees and wires were blown down, windows were broken, and a yacht was sunk in the harbor. The maximum wind was 36 miles from the southwest. At Superior, in the extreme northwestern portion of the State, the high wind caused considerable damage to growing crops. The maximum wind at Duluth was 64 miles from the northwest. Between these two extreme points the degree of damage varied greatly. It was most serious over a belt about 100 miles wide extending from southwest to northeast across Wisconsin, the southern edge of the belt passing just north of the center of the State.

Within this belt there were certainly two, and possibly four, tornadoes. Fortunately, much of this section is very sparsely settled; otherwise the loss of life and property would have been much greater. Where the tornadoes passed over the more densely populated regions the destruction was very great. A statement from the Governor of Wisconsin says that 36 people were killed, 61 seriously injured, 65 to 75 homes entirely destroyed, about 25 homes more or less damaged, and that the monetary loss would exceed $800,000. Probably more than 100 people received minor injuries, more than 200 head of cattle and horses were killed, and more than 200 barns were destroyed.

There were two principal tornadoes. One of these originated apparently about 2 p. m. near Chetek, in southeastern Barron County, and traveled about north-northeast through eastern Barron County, and northwestern Rusk County, passed diagonally across Sawyer County and probably across the southeastern corner of Bayfield County, and was last seen in northern Ashland County near Marengo. The length of the path was about 90 miles, assuming that it was continuous. Of this we are not certain, as from about the middle of Sawyer County to well up in Ashland County the path is through practically uninhabited territory. Over a stretch of about 45 miles there are no post offices, and no reports were received from that section.

From the best obtainable information it appears that there was one fatality and a property loss of about $170,000 in Barron County. In Rusk County no fatalities were reported; the property loss was about $30,000. In Sawyer County two fatalities were reported and the property loss was about $10,000. This was in the southwestern part of the county; as previously stated the path from there to the northern portion of Ashland County is through practically uninhabited country. In the northern portion of Ashland County seven fatalities and a property loss of about $40,000 were reported. Apparently the storm lost its tornado characteristics while still some 15 miles from Lake Superior. Several people at Meteor, Sawyer County, say there were two funnel-shaped clouds. No attempt has been made to estimate the speed with which this tornado traveled, because of the apparently unreliable nature of many of the time reports.

The second tornado formed about 2:20 p. m., some 2 miles east and 1 mile south of Augusta, Eau Claire County, and moved northeast across northern Clark County, extreme northwestern Marathon County, eastern Taylor County, Lincoln County, and was last reported in the vicinity of Three Lakes in the northeastern corner of Oneida County, about 4:30 p. m. The distance traveled is about 120 miles, and if the times reported are approximately correct, it traveled nearly 60 miles an hour. This tornado also passed over wide stretches of country that are practically uninhabited. Wherever there were settlements, however, great destruction occurred. The following fatalities and property losses were reported: In Eau Claire County a property loss of about $4,000, mainly to rather frail buildings; in Clark County, 14 fatalities and a property loss of about $180,000; in Taylor County, 4 fatalities and a property loss of about $45,000; in Lincoln County, 2 fatalities and a property loss of about $80,000; in Oneida County 6 fatalities and a property loss of about $255,000.

In addition to the foregoing a property loss of about $4,000 was reported about 4 miles southeast of Antigo, Langlade County. This probably was from a small tornado which is believed to have formed about 25 miles south of the main storm track. It was not reported from any other point, but the reporter says it had all of the tornado characteristics. It is possible that a small tornado may have formed north of the main track also, as at the time the principal storm was passing near Rhinelander, 4 p. m., a destructive storm with a funnel-shaped cloud was reported at Minocqua, 25 miles northwest of there. This tornado, like the one near Antigo, was not reported from any other point.

The width of the path of great destruction in all of these tornadoes varied greatly from place to place; at some points it was not over 200 feet, while at others it was more than half a mile. The estimates of losses were made by the postmasters in the various localities. They include the damage to crops, mainly corn and apples. Corn was blown flat and trees stripped of fruit over a large part of northern Wisconsin. In the path of the tornadoes much timber is reported down.

[1] The tornadoes herein described occurred on the right side and close to the center of the cyclonic storm that was centered between St. Paul, Minn., and Charles City, Iowa, at 8 a. m. 75th meridian time and moving toward the northeast. See track No. VI, chart No II, this REVIEW. The significant feature of the weather chart on the morning of the 21st was the high temperature in the southeastern quadrant of the cyclone. Charles City, Iowa, about 130 miles south of St. Paul, was 10° warmer than the latter, and in general warm south to southeast winds were blowing towards the center of the cyclone, while much cooler northwest winds were blowing around the center in the rear. The tornadoes did not occur until after 2 p. m. about which time the wind-shift line must have been passing over northwestern Wisconsin.—EDITOR.

RAINFALL AND DRAINAGE OPERATIONS

By E. V. WILLARD, Commissioner of Drainage and Waters, Minnesota

The Weather Bureau is occasionally asked as to the effect of the drainage of marshes, sloughs, and small lakes upon the rainfall of the region so drained.

Mr. E. V. Willard, Commissioner of Drainage and Waters, State of Minnesota in an address on February 1, 1924, before the Minnesota Federation of Architectural and Engineering Societies took for his subject "Drainage development in its relation to wild animal and plant life and rainfall.[1]

Mr. Willard showed from the rainfall records maintained by the Weather Bureau in Minnesota both before and after drainage operations were begun that the rainfall of the second period was slightly greater than that of the first. His findings are so closely in accord with those that would be reached from a consideration of the physical features of the problem that they are reproduced in the paragraph below:

* * * But the judicious observer with an orderly mind recognizes that, while the available records conclusively dissipate the charge that reclamation by drainage has caused a reduction of rainfall in Minnesota, he acknowledges the varied and undeterminable influences of the other human activities which may or may not affect climate, and does not seize upon the slight advantage in rainfall during the past 20-year period shown by the comparisons made herein, and credit such increase to the effects of drainage. He knows that drainage has not affected rainfall; that the present-dry cycle is not unlike many others which have come and gone in the past; that no records are being broken; that wet cycles will alternate with dry ones; and that when the leaders of sportsmen's organizations, and those who are so deeply concerned with retaining nature as "God Almighty made it" seize upon drainage as the cause of all disturbing elements, they are either desperately in need of something upon which to make an issue or they are inexcusably ignorant of facts which are easily within their reach.—*A. J. H.*

[1] Bulletin Minnesota Federation of Architectural & Engineering Societies, Vol. 9, number 3, pp. 14-25.

THE CLIMAGRAM

By G. HELLMANN

[Translated from Met. Zeit. 41, September, 1924, p. 278, by B. M. Varney]

In presenting climatological data in my lectures on climatology I have occasionally made use of a device which, if incorporated in a general formula, such as the one given below or in a similar form, would be of great use in many connections. I called it at first a climatic formula, but since in the meantime this expression has been used by W. Köppen to designate a scheme for the description of a climatic province, I prefer to call it a climagram. Its construction is based on the often used principle of the code telegram employed in the telegraphing of weather observations. The order in which the letters are given always follows a stipulated arrangement, so that the addition of further notations among the characters, as for example in this case of the climatic elements, is unnecessary. We are concerned, then, only with the question of deciding what climatic characteristics it is necessary to include in the description and in what order these should appear. I think that the mean values for the year and for the extreme months, for temparature, moisture, cloudiness, and precipitation, together with the average and absolute extremes of temperature, are sufficient.

An example will serve to make this clear:

Climagram of Berlin (32 m.)

$$9.2\,\frac{18.9}{-0.4}\,\frac{(33.2)}{(-13.8)}\,\frac{37.0}{-25.0}\;\Big|\;6.9\,\frac{10.8}{4.0}\,76\,\frac{87}{64}\;\Big|\;6.4\,\frac{7.6}{5.7}\Big|\;582\,\frac{75}{38}\,169\,\frac{16.2}{12.5}$$

It is evident that the first group has to do with temperature; the second with moisture, absolute and relative; the third with cloudiness; the fourth with precipitation, its depth in millimeters and the number of days of occurrence. Addition of degree signs and per cent signs is superfluous. Moreover, I have placed in parentheses the average temperature extremes (not usually indicated) so that when they are given there is no doubt as to whether one is dealing with the mean extremes or with the absolute extremes. Similarly, if in the case of moisture one of the values is missing, there can be no uncertainty. If it is desired, furthermore, to indicate to what months the extreme monthly means belong, one simply need affix the number of the month in Roman letters. This should be done preferably only when the occurrence fails to coincide with the usual extreme months, namely January and July.

Thus:

Climagram of Rome (36 m.)

$$15.4\,\frac{24.5}{7.0}\,\frac{42.0}{-8.2}\Big|\;9.3\,\frac{13.2}{5.7}\,65\,\frac{74}{55}\;\Big|\;4.4\,\frac{5.5\,\text{III}}{2.0\,\text{VII}}\Big|\;827\;\;\frac{127\text{X}}{18\text{VII}}\;\Big|\;99\;\;\frac{11.5\text{XI}}{2.2\text{VII}}$$

In case one or another of the specifications is not made, no misunderstanding can occur, provided the sequence of the arrangement is rigidly adhered to. The altitude of the station, standing next after its name, is a sufficient indication of its mean atmospheric pressure.

In printing the formulae one should take care that in using small letters for those specifications which are given in fractional form, the height of the row be not [greatly] exceeded.

If the abundant and very useful specifications of climates in Köppen's Climates of the Earth were given in the form of climagrams, they would take up considerably less space, and one would not have to search for them in two different tables.

THE FREE ATMOSPHERE IN INDIA [1]

(Reprinted from Nature, 114, No. 2864, September 20, 1924)

The memoirs before us are by Mr. J. H. Field, who has succeeded Sir Gilbert Walker at Simla, and by Dr. W. A. Harwood. They are of particular interest from the fact that both authors have been connected with upper-air work in England almost from its first conception.

In the introduction, Mr. Field discusses the methods and instruments that were used, many of which were designed by him especially for the purpose; and he is to be congratulated on the success that has been attained.

Owing to the climate of India the ordinary rubber balloons could not be used, on account of the difficulty of storage, and gutta-percha balloons, made up as required, were substituted for them. Mr. Field describes his semigraphical methods of working up theodolite observations quickly, and gives some very useful formulæ showing the final error in terms of the errors of observation. He finds that too much trust may easily be placed in the two-theodolite method, and gives an example in which the four angular measurements are perfectly consistent among themselves and yet the height of the balloon is in error by 50 per cent. He adopted the tail method for general use.

The results of some very useful experiments are given, showing the extent of the errors which may occur owing to the heating by solar radiation of the recording instruments, and also by the inevitable lag of the thermograph. The conclusion reached is that the resulting error is small up to a height of 6 kilometers, and this is confirmed by the good agreement of the mean values obtained by night and by day. Above 10 kilometers the error is increased by the unfortunate necessity in having to use gutta-percha balloons, the rising velocity of which falls off as their highest point is reached; but up to 12 kilometers it does not seem likely that the error exceeds two or three degrees.

In Part VI, Doctor Harwood discusses the observations made with kites and registering balloons over India and the Arabian Sea. He gives first a summary of the results obtained by Field by means of kites, and then deals with the registering-balloon ascents made in India, chiefly at Agra, during the years 1914–1918. In all 237 were sent up, 156 instruments were returned, and 152 of these gave usable records. * * *

Doctor Harwood has taken every care to insure accuracy, and being well acquainted with the many possible sources of error, has only used such ascents as may be reasonably supposed to be free from error, especially from the effects of solar radiation, a precaution needful in view of the slow rise of gutta-percha balloons. He gives particulars of the temperature, humidity, and pressure at various heights in the three Indian seasons—the cool, the hot, and in the monsoon—and also annual means for the density. He carries his tables up to 12 kilometers, and it is only to be regretted that the stratosphere was not reached, and that at least the results from Agra are not published in full detail.

It is not possible to comment on the many interesting points discussed, but the following may be mentioned. The mean annual lapse rate comes out as identical up to 9 kilometers with that of nearly all other stations; so also the daily temperature variation in India, as elsewhere, is confined to the first 1 or 2 kilometers. The excessive heat of the hot season is found to be confined to the bottom layer; higher up the monsoon season is the hottest. The high correlation between pressure and temperature so noticeable in Europe is absent in India, perhaps because the short period variations of pressure are too small.

Comment is made on the figures for the Equator given by the reviewer in the M. O. Geophysical Memoir, No. 13, and the absence of information as to their source. These figures were formed from the smoothed mean values derived from the few data available at that time. Further observations on the Equator are necessary to show whether van Bemmelen's excellent set of results from Batavia, most of which have been published since then, fairly represent the general equatorial conditions.

Parts VII and VIII discuss the motion of the free air over India as it is observed by means of clouds and pilot balloons. The year is divided into three seasons, and three separate heights are taken—the height of low clouds, 2 kilometers; of middle clouds, 5 kilometers; and of high clouds, 9 kilometers. These are the heights assigned to the different clouds in the International Cloud Atlas, and Doctor Harwood accepts them as correct for India. Many tables are given showing the direction of the wind and the percentage frequencies for each direction at each height for 15 stations distributed over the peninsula; in some cases separate values for each month are given. It is noted that cloud observations necessarily refer to cloudy weather and that pilot-balloon observations will refer chiefly to clear weather, and there is some evidence that there is a systematic difference between the two, but it does not seem to be large enough seriously to prejudice the results of using them as equivalent. The figures will be of great interest to anyone who is endeavoring to elucidate the cause of the monsoons.

In Part VIII the relation of the monsoons to the general circulation of the atmosphere is dealt with, and the similarity of the northeast monsoons to the circulation over the North Atlantic is discussed. Doctor Harwood finds a very noticeable coincidence between the track of storms and depressions, as shown in the Climatological Atlas of India and in the Meteorological Atlas of the Indian Sea, and the monthly mean directions of the upper winds at the cirrus level. If this be more than a coincidence, and it seems to be so, it has an important bearing on the formation and propagation of cyclones, and shows that their source must be sought for in the upper winds rather than in the surface conditions.

The four Memoirs form a very valuable contribution, not to Indian meteorology only, but also to meteorology in general.— *W. H. Dines.*

[1] "Memoirs of the Indian Meteorological Department." Vol. xxiv., Parts v, vi, vii, and viii.

WIND, WAVE, AND SWELL ON THE NORTH ATLANTIC OCEAN [1]

(Reprinted from Nature, No. 2863, September 13, 1924)

During a voyage from Southampton to Trinidad and back by R. M. S. *Oruba* the period of the waves was taken several times daily, and from this their speed was calculated. The speed of the wind was ascertained by means of a Robinson anemometer (lent by the Meterological Office), due allowance being made for the speed of the ship and the direction of the wind.

The water is very deep from a short distance beyond Ushant, and free from strong currents so far as Barbados. The speed of the wind ranged from 13.9 to 23.6 statute miles per hour. That of the waves was in all cases less, the difference ranging from 1.0 mile an hour to a little more than 8.0 miles an hour. The latter is sufficient to keep a light flag flying. Anything less than 1 mile an hour is reckoned a calm. The difference was not proportional to the speed of the wind; nevertheless a relationship emerges when account is taken of the observations which were made simultaneously of the swell of the sea. When swell and wave ran precisely in the same direction (as sometimes occurred in the region of the trade winds) and on one day when no swell was recorded, the speed of the wave was so nearly equal to that of the wind that the breeze blowing over the ridges was only equal to the "light air" which barely suffices to give steerage way to a fishing smack. Such a light air would be detected on land by drift of smoke but would not move a wind vane. Thus there was no longer a battle between wind and wave.

When the swell followed but crossed the wave the difference in speed of wind and wave was greater, and this difference increased rapidly when the crossing swell was meeting, instead of following, the wave. When the waves were much slower than the wind their height was always small, and sometimes their fronts were short and irregular. It was evident that the growth of waves in both length and height was much hindered by a crossing swell, and it can be safely inferred that the general absence of swell is a sufficient reason for the rapid rise of waves upon inclosed seas. When a wind comes on to blow in the direction of the ocean swell with a speed greater than that of the swell, the growth of large, steep waves is very rapid (doubtless even more rapid than their growth from smooth water), but this occurrence is relatively rare in the North Atlantic.

The direction of the breaker out at sea was found to be intermediate between that of wave and swell (the breaker being formed when they override), so that the practice of observing the direction of "the curl on the water" as a method of determining the direction of the wind gives an erroneous result whenever there is a crossing swell, which is the usual condition upon the oceans. The general run of the waves, on the contrary, gives a trustworthy indication of the direction of the wind.

BAROGRAM ANALYSIS IN WEATHER FORECASTING

[Reprinted from Nature, No. 2863, September 13, 1924]

The Italian meteorologist, Francesco Vercelli, has made a laborious study of barographic records from various parts of the world, and various periods and seasons, submitting these curves to a process of periodigram analysis on the lines familiar in tidal investigations, or as applied to the study of seiches in lakes by the late Professor Chrystal. The results are described in full detail in a booklet published last year in Rome, under the auspices of the Geophysical Institute of Trieste, entitled "Nuovi esperimenti di previsioni meteorologiche."

From the generalized point of view, the barometric curves are shown to contain the well-known diurnal period which is so outstanding in the Tropics, various periods ranging between a few days and a month, and an annual period, together with a small "insoluble residue," representing what must be regarded as irregular fluctuations. The amplitudes of these several periods, and other characteristics thereof, differ greatly according to the latitude, season, and continentality. If the periodical composition of a given barogram is known, it becomes possible to synthesize its prolongation on the assumption that none of the contained periods die out or others reappear, and thus to make a forecast of the course of barometric pressure for a longer period than is possible by the ordinary synoptic chart method.

Vercelli claims—and the responsibility for the statement must rest with him—to have obtained remarkably good agreement between the predicted and actual continuations of his curves, and to have used this method of weather forecasting with much success in circumstances of grave responsibility on the Italian front during the War. He indicates the main source of error to be the liability to cessation, or temporary suspension, of any of the component periods, or the reappearance of others. He also points out that the paper in question, discussing the analysis of single curves, is only the commencement of the subject, since the next step will consist in coordinating the analyses of curves from several places; this would greatly enhance the usefulness of this method of forecasting.

The author does not, however, appear to lay enough stress on the fact that forecasting pressure is by no means equivalent to forecasting weather, and that the correlation between rainfall and the height of the barometer at a place, or even the connection between rainfall and pressure distribution over an area, is none too close from a forecaster's point of view. One has also to consider the tendency of the weather to get into dry or wet "grooves"; for it is well known that during pronouncedly wet spells, downpours occur in passing barometric configurations that would scarcely yield a drop during a dry spell. Moreover, it does not follow that Vercelli's method, even if found practicable in Italy, would answer in England, where it is possible that the relationship between pressure and weather may be rather more complex. It is just such climatic peculiarities we want to discover, and it not too much to say that even if a universal application of Vercelli's system to weather forecasting proved wholly unserviceable, which is scarcely likely, it could not fail to bring to light any such interesting climatological differences between one region and another.—*L. C. W. Bonacina.*

"WHY THE WEATHER" [2]

Most, if not all, REVIEW readers are familiar with the series of *Science Service* notes on "Why the Weather" that have been running in newspapers of the United States and Canada for about a year and a half.

[1] Substance of a paper by Dr. Vaughan Cornish read before Section E (Geography) of the British Association at Toronto on Aug. 8.

[2] Brooks, Charles Franklin, Why the Weather. Harcourt, Brace & Co., New York, 1924.

The author of the notes, Dr. C. F. Brooks, is Associate Professor of Meteorology and Climatology in Clark University. Associated with him in the preparation of the material were John Nelson and Eleanor Stabler Brooks. Each note presents in nontechnical language a summary averaging 250 to 300 words in length of what is known or inferred of the various subjects treated. The first note discussed the topic "Dust is all important" and the four hundred and sixty-seventh, which happens to be the last one available to the reviewer, bears the title "The lakes as storm magnets."

In the volume under review the author has brought together in logical sequence, beginning with the spring season, the essential facts of the weather of that season and their explanation as they appear from the viewpoint of a close student and observer of the weather. Doctor Brooks is known to be one of our keenest observers of weather phenomena. Although the book treats of many phases of the weather, the facts presented are woven into a connected story and the interest of the reader is sustained throughout.—*A. J. H.*

LOSS OF FORTY-SEVEN HEAD OF CATTLE BY A SINGLE LIGHTNING BOLT

The Hancock (Minn.) Record of August 8, 1924, contains an account of the killing of 47 head of cattle during a thunderstorm (without rain). The cattle had crowded together under the branches of a large spreading willow tree. The tree and the cattle under it were struck by lightning and the latter dropped in their tracks. Bodily contact seems to have provided the means of conveying the charge to the animals.—Reported by Junior Meteorologist William E. Maughan.

BIBLIOGRAPHY

C. FITZHUGH TALMAN, Meteorologist in Charge of Library

RECENT ADDITIONS

The following have been selected from among the titles of books recently received as representing those most likely to be useful to Weather Bureau officials in their meteorological work and studies.

Ångström, Anders.
Preliminär undersökning rörande temperaturförhållanden över torr och sank mark. [Stockholm. 1924.] 7 p. illus. 20½ cm. (Repr.: Teknisk tidskrift 1924, häft 4. Väg=och vattenbyggnadskonst 1.)
Studier av Sveriges strålningsklimat. [Stockholm. 1924.] 23 p. illus. 23½ cm. (Ymer, Tidskrift utgiven av Svenska sällskapet för antropologi och geografi. Årg. 1924, H. 1.)
Studies of the frost problem. no. 3. [Stockholm. 1923.] p. 401–412. figs. 25 cm. (Geografiska annaler. H. 4, 1923.)

Carpenter, Ford A.
Hythergraph: an instrument for recording humidity and temperature. Some of the local winds of the western coast of North America. Notes on the irregularities of ocean currents. p. 75–102. illus. 25½ cm. (Bulletin Southern California acad. sci., v. 20, no. 3, May–June, 1924.)
Weather methods. Illustrated reprints. n. p. n. d. v. p. illus. 27½ cm.

Davis, John King.
Willis Island, a storm warning station in the Coral sea ... With an introductory chapter by Griffith Taylor. Melbourne. 1923. 119 p. illus. plates. 22 cm.

Defant, Albert.
Die Windverhältnisse im Gebiete der ehemaligen Österr.-Ungar. Monarchie. Wien. 1924. 14 p. fig. plates. 30½ cm. (Anhang zum Jahrbuche der Zentral-Anstalt für Meteorologie und Geodynamik, Wien. Jahrg. 1920, neue Folge, 57. Bd.)

Diaz, Severo.
El primer año de previsión del tiempo en Guadalajara. pt. 1–2. Guadalajara. 1922–24. 2 pts. 28 cm.

Eriksson, J. V.
Mälarens isförhållanden vintrarna 1917/18–1921/22. Stockholm. 1924. 19 p. illus. plates. 31½ cm. (Meddelanden från statens meteorologisk-hydrografiska anstalt. Bd. 2, No. 2.)

Farr, C. Coleridge.
Report on Samoan observatory. Wellington. 1924. p. 318–327 25 cm. (New Zealand journ. sci. & tech., v. 6, nos. 5–6, 1924.)

Friedley-Voshardt co., inc.
Weather vanes. Chicago. n. d. 16 p. illus. 23 cm.

Great Britain. Meteorological office.
International code for weather reports from ships at sea. London. 1924. 3 + p. forms. 33½ cm.

Gregory, Richard.
British climate in historic times. Presidential address. n. p. n. d. unp. figs. 25½ cm. (Repr.: Spring and summer nos., Geographical teacher.)

Hellmann, G.
Beitrag zur Gewitterkunde. Berlin. 1924. p. 43–51. 25 cm. (Extr.: Bericht über die Tätigkeit des Preuss. met. Inst., 1920–1923.) (Veröff. Preuss. met. Inst., Nr. 320).

Herdman, William Abbott.
Founders of oceanography and their work; an introduction to the science of the sea. New York. 1923. xii, 340 p. front. illus. plates. 22½ cm.

Hill, Leonard Erskine.
Sunshine and open air, their influence on health, with special reference to the Alpine climate. London. 1924. vii, 132 p. plates. diagrs. (1 fold.) 22½ cm.

Home insurance co.
Rate manual. Rain insurance. General rules. [New York. 1924.] 18 p. 20½ cm.

International geodetic and geophysical union. Section of meteorology.
Rapport sur la prévision du temps. Roma. 1924. 51 p. 23 cm. [Manifolded.]

Letzmann, Johannes.
Das Bewegungsfeld im Fuss einer fortschreitenden Wind- oder Wasserhose. Dorpat. 1923. 136 p. figs. 22½ cm.

Lou, Kao.
Unification of meteorological signals. Peking. n. d. 3 p. figs. plates (fold.)

Lowdermilk, W. C., & Hsioh-li, Shen.
Summary university meteorological records. 1895–1923. [Nanking.] 1924. unp. 22 cm. (Univ. Nanking. Agric. & forestry series. v. 1. no. 8.)

McConnell, W. J., & Yagloglou, C. P.
Katathermometer: its value and defects. p. 2293–2308. diagr. 23½ cm. [With bibliography.] (U. S. Public health reports. v. 39, no. 36, Sept. 5, 1924.)

Mathias, E.
Rapport sur l'état actuel de l'électricité atmosphérique. Paris. 1922. p. 83–170. 23 cm. (Extr.: Annales de physique. 9e sér., T. 18, juil.-août, 1922.)

Medical directory. Health resort section.
Medical guide to the principal British spas and climatic health resorts. 1924–5 ... London. [1924.] 90 p. illus. plates. 25 cm.

Melander, G.
Sur l'origine commune de toutes les décharges électriques dans l'atmosphère. Helsinki. 1924. 30 p. illus. 25 cm. (Annales acad. scient. fennicae. ser. A., T. 23, No. 6.)

Mörikofer, Walter.
Beobachtungen zur Theorie des Malojawindes. [Basel. 1924.] 33 p. 23 cm. ((Repr.: Jahresb. Naturforsch. Gesellsch. Graubündens. Bd. 63, 1924.)

Moltchanov, P.
Nëkotoriîa danniîa o struktuřě vozdukha nizhnikh sloev atmosferi ... [Some information on the structure of the lower atmosphere.] Petrograd. 1918. 23 p. 25½ cm. [Author, title and text in Russian.]

Mott, J. L., iron works.
Copper weather vanes. New York. n. d. 30 p. illus. 24 cm.

Passarge, Siegfried.
Die Landschaftsgürtel der Erde, Natur und Kultur. Breslau. 1923. 144 p. illus. (fold. map). plates. 19 cm.

Réthly, Antal.
Nyiregyháza éghajlata. [Climate of Nyiregyháza.] Nyiregyháza. 1924. p. 91–129. illus. 23½ cm. [Author, title and text in Hungarian.]

Rochester bureau of municipal research, inc.
Report on the problem of snow removal in the city of Rochester, N. Y. ... [Rochester.] 1917. 44 p. plates. 23 cm.

Sifontes, Ernesto.
Notas sobre la lluvia en Ciudad Bolívar en 1924. Bolívar. 1924. sheets. 61 cm. (El Luchador. Agosto 16, 1924.)

Stewart, P. H., & Wood, I. D.
Soil washing. The cause and methods of prevention. [Lincoln.] 1924. 34 p. illus. 22½ cm. (Univ. Nebraska, Agric. coll. exten. serv. Extension circular 123, June, 1924.)

Tengwall, T. A., & Van Der Zyl, C. E.
Het verband tusschen klimaat en suikerproduct op Java. Soerabaja. [1924.] p. 65–139. figs. 26½ cm. (Archief voor de suikerindustrie in Nederlandsch-Indië. Mededeelingen van het proefstation voor de Java-suikerindustrie. Jaarg. 1924, no. 4.)

Topolansky, Moriz.
Laboradomanieroj de la klimatologio. 8 p. 26 cm. (Repr.: Met'l soc. Japan. Journal, 43d year, 1924.)

Turkestan. Meteorologicheskogo instituta.
Klimaticheskoe raĭonirovanie Turkestana. [Climatic conditions in Turkestan.] Tashkent. 1924. ii, 29–39 p. map. 26½ cm. [Author, title, and text in Russian.]

Visher, Stephen Sargent.
Climatic laws; ninety generalizations with numerous corollaries as to the geographic distribution of temperature, wind, moisture, etc.; a summary of climate. New York. 1924. 96 p. illus. (maps.) diagrs. 23½ cm.

Wallén, Axel.
Le débit des fleuves suédois et le rapport de ce débit avec l'eau tombée. [Stockholm. 1924.] p. 42–55. diagr. plate 25 cm. (Geografiska annaler, H. 1, 1924.)
Nederbördskartor över Sverige. Stockholm. 1924. 8 p. figs. plates (part fold.) 31½ cm. (Meddelanden från Statens meteorologisk-hydrografiska anstalt. Bd. 2, No. 3.)

Wigand, A.
Flugzeug-Meteorographen. n. p. n. d. 16 p. illus. 22 cm. (Extr.: Feinmechanik und Präzision.)

RECENT PAPERS BEARING ON METEOROLOGY AND SEISMOLOGY

The following titles have been selected from the contents of the periodicals and serials recently received in the Library of the Weather Bureau. The titles selected are of papers and other communications bearing on meteorology and cognate branches of science. This is not a complete index of all the journals from which it has been compiled. It shows only the articles that appear to the compiler likely to be of particular interest in connection with the work of the Weather Bureau.

Akademie der Wissenschaften. Sitzungsberichte. Wien. Abt. IIa. Bd. 132, H. 7 & 8. 1924.
Kofler, Martin, & Wagner, Artur. Ergebnisse der Pilotanvisierungen auf dem Hochobir (2043 m) im Jahre 1913–14. p. 233–253.

American journal of botany. Lancaster, Pa. v. 11. October, 1924.
Adams, J. Does light determine the date of heading out in winter wheat and winter rye? p. 535–539.

American society of civil engineers. Transactions. N. Y. v. 87. 1924.
Cox, Joel B. Periodic fluctuations of rainfall in Hawaii. p. 461–491.
Marston, Frank A. The distribution of intense rainfall and some other factors in the design of storm-water drains. p. 535–588.

Discovery. London. v. 5. October, 1924.
Walford, Eric W. The great dew pond myth. p. 245–246.

17407—24†——3

France. Académie des sciences. Comptes rendus. Paris. t. 179. 1924.
Eredia, Filippo. Les dépressions secondaires de la mer Adriatique. p. 65–67. (7 juil.)
Petitjean, L. Sur l'application de la frontologie aux dépressions. p. 64–65. (7 juil.)
Vegard, L. Les spectres lumineux de l'azote solidifié et leur application aux aurores boréales et à la lumière diffuse du ciel nocturne. p. 35–37. (7 juil.)
Cabannes, J. Sur la transparence de l'atmosphère. p. 191–193. (21 juil.)
Mathias, E. Sur les formes terminales des éclairs fulgurants. p. 136–139. (21 juil.)
Vegard, L. La luminescence des gaz solidifiés et leur application à des problèmes cosmiques. p. 151–153. (21 juil.)
Gazaud, L. Sur les zones de silence. p. 284–285. (28 juil.)
Schereschewsky, Ph., & Wehrlé, Ph. Les courants de perturbations et le front polaire. p. 285–288. (28 juil.)
Guinchant, J. Rôle de l'atmosphère dans la propagation des ondes hertziennes. p. 327–330. (4 août.)
Bureau, R., & Viaut, A. Conditions météorologiques de l'apparition de certaines perturbations atmosphériques dans les appareils récepteurs de T. S. F. p. 394–397. (18 août.)
Mathias, E. Sur le bruit de l'éclair. p. 372–374. (18 août.)

Heating and ventilating magazine. New York. v. 21. October, 1924.
Who's who in heating and ventilation. IV—E. Vernon Hill, p. 61–63. [With portrait.]

Meteorologische Zeitschrift. Braunschweig. Bd. 41. September, 1924.
Dorsch, Fr. Kant und die Meteorologie. p. 280–282.
Droste, Bernhardine. Die elfjährige Sonnenfleckenperiode und die Temperaturschwankungen auf der nördlichen Halbkugel in jahreszeitlicher und regionaler Differenzierung. p. 261–268.
Groissmayr, Fritz. Die Anomalie der Jahrestemperatur in Bezug auf die Extrem-Monate. p. 282–285.
Hellmann, G. Frühe Regenmessungen an Bord von Schiffen. p. 278–280.
Hellmann, G. Das Klimagramm. p. 278.
Johansson, Oskar V. Die Asymmetrie der Temperatur. p. 285–286.
Moltschanoff, P. Die Höhe der Wolken im Zusammenhang mit den Feuchtigkeits-Verhältnissen an der Erdoberfläche. p. 286–288.

Nature. London. v. 114. September 27, 1924.
Wright, C. S. Aurora, potential gradient and magnetic disturbance. p. 466–467.

Nature. Paris. 52 année. 4 octobre 1924.
Baldit, A. Le ballon libre et l'électricité atmosphérique. p. 209–213.

Naturwissenschaften. Berlin. 12. Jahrg. 3. Oktober 1924.
Milch, Wilhelm. Ist die Solarkonstante Schwankungen unterworfen? p. 826–827.

Popular science monthly. New York. v. 105. November, 1924.
McLoud, Norman C. Who says the weather man is always wrong? p. 52–53; 158–159.

Scientific American. New York. v. 80. November, 1924.
The physics of snow. p. 329.

Tycos-Rochester. Rochester, N. Y. v. 14. October, 1924.
The daily weather map. p. 36–37.
Flora, S. D. Measuring evaporation. p. 24; 38.
The fog hazard in aviation. p. 34; 35.
The kata-thermometer. p. 27. [Repr. Engineering & mining journal-press.]
Luckiesh, M. The sky by day. Solved and unsolved problems which it places before our eyes. p. 17–19. [Repr. Sci. American.]
Pearson, S. K., Jr. How weather man obtains temperature readings. p. 28.
Wall Street and the weather. p. 15. [From Bache review.]
Winter temperatures in beehives. p. 16.

Zeitschrift für Geophysik. Braunschweig. 1. Jahrgang 1924–25. Heft 1–2.
Angenheister, G. Das Polarlichtspektrum und die Konstitution der oberen Atmosphäre. p. 70–74.
Linke, F. Die Verwertung von Sonnenstrahlungsmessungen. p. 55–59.

SOLAR OBSERVATION

SOLAR AND SKY RADIATION MEASUREMENTS DURING SEPTEMBER, 1924

By HERBERT H. KIMBALL, In Charge, Solar Radiation Investigations

For a description of instruments and exposures and an account of the method of obtaining and reducing the measurements, the reader is referred to the REVIEW for January and February, 1924, **52**:42 and 113.

From Table 1 it is seen that solar radiation intensities averaged above normal at all three stations.

Table 2 shows that the total solar and sky radiation received on a horizontal surface averaged below normal at the three stations for which normals have been determined.

Skylight polarization measurements made on 5 days at Washington give a mean of 50 per cent, with a maximum of 52 per cent on the 6th. Measurements obtained on 12 days at Madison give a mean of 68 per cent, with a maximum of 71 per cent on the 5th and 30th. The values for Washington are slightly below, and those for Madison approximate closely the averages for September for the respective stations.

TABLE 1.—*Solar radiation intensities during September, 1924*

[Gram-calories per minute per square centimeter of normal surface]

Washington, D. C.

Date	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	A. M.					P. M.				Local mean solar time
	e	5.0	4.0	3.0	2.0	[1]1.0	2.0	3.0	4.0	5.0	e
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Sept. 2	18.59				0.87						19.23
4	9.14	0.73	0.86	1.00	1.17	1.38					8.48
6	6.76	0.78	0.95	1.09	1.21						5.79
10	6.27	0.89	1.00	1.12	1.31						5.79
11	7.04				1.22	1.40					6.02
18	10.21				0.84						9.83
23	7.87	0.86	0.95	1.06	1.28	1.55	1.27	1.04	0.93	0.80	7.87
24	6.50	0.92	1.03	1.16	1.30	1.46					6.50
Means		0.84	0.96	1.09	1.15	1.45	(1.27)	(1.04)	(0.93)	(0.80)	
Departures		+0.16	+0.21	+0.21	+0.11	+0.13	+0.22	+0.20	+0.21	+0.14	

[1] Extrapolated.

TABLE 1.—*Solar radiation intensities during September, 1924*—Con.

Madison, Wis.

Date	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	A. M.					P. M.				Local mean solar time
	e	5.0	4.0	3.0	2.0	[1]1.0	2.0	3.0	4.0	5.0	e
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Sept. 2	8.81			1.13	1.28	1.48					7.57
3	7.57			1.06	1.24						9.14
5	7.29			1.16	1.33	1.50					5.56
9	6.27		1.06	1.21	1.33	1.51	1.34				6.27
17	8.81					1.38					9.14
22	6.02		1.05	1.15	1.30	1.46	1.28				6.50
23	7.57			1.05	1.31	1.45	1.24	1.06	0.90		6.02
25	7.87						1.01				10.59
29	5.16			1.12	1.32						4.95
30	4.75		1.14	1.26	1.38	1.49	1.36	1.21			4.57
Means			1.08	1.14	1.31	1.47	1.25	(1.14)	(0.90)		
Departures			+0.16	+0.10	+0.13	+0.08	+0.08	+0.12	+0.04		

Lincoln, Nebr.

Date	e	5.0	4.0	3.0	2.0	1.0	2.0	3.0	4.0	5.0	e
Sept. 2	7.57	0.66	0.87	0.99	1.12	1.43	1.23	1.01	0.85	0.76	7.57
3	7.87	0.83	0.93	1.06	1.22	1.40	1.17				9.14
4	9.83	0.61	0.70	0.82	1.08	1.33	1.19	1.04	0.92	0.82	14.10
5	7.87		0.89	0.98	1.25	1.47	1.14	0.93	0.76	0.62	6.50
8	8.48						1.19	1.05	0.90	0.80	9.47
12	7.29			1.09	1.28	1.49					7.87
22	5.79			1.07	1.29	1.53	1.22	0.98	0.77		4.57
23	6.50		1.04	1.17	1.30	1.49					5.36
24	8.18		1.02	1.13	1.29	1.44	1.21	1.01	0.86	0.74	7.04
25	8.81		0.76	0.87	1.01	1.16	1.41				9.14
29	4.17						1.30	1.18	1.06	0.93	4.17
30	4.95	0.93	1.02	1.15	1.30	1.45	1.22	1.04	0.88	0.76	4.95
Means		0.76	0.92	1.05	1.23	1.44	1.21	1.03	0.88	0.78	
Departures		+0.01	+0.06	+0.04	+0.04	+0.04	+0.05	+0.05	+0.05	+0.05	

TABLE 2.—*Solar and sky radiation received on a horizontal surface*

[Gram-calories per square centimeter of horizontal surface]

Week beginning—	Average daily radiation					Average daily departure from normal		
	Washington	Madison	Lincoln	Chicago	New York	Washington	Madison	Lincoln
	cal.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Sept. 3	454	366	515	300	356	+62	−10	+78
10	375	271	295	238	321	+2	−78	−116
17	206	322	334	338	276	−154	−5	−56
24	243	320	415	277	280	−104	+15	+44
Excess or deficiency since first of year on Sept. 30, 1924						−248	−7984	+2665

CORRECTION

REVIEW, August, 1924, page 400: In Table 1, Washington, the means (next to bottom line) of the P. M. columns headed Air Mass 2.0, 3.0, and 4.0, given as 1.01, 0.88, and 0.73, respectively, *should be* 1.07, 0.96, and 0.82.

WEATHER OF NORTH AMERICA AND ADJACENT OCEANS

NORTH ATLANTIC OCEAN

By F. A. YOUNG

The following table shows the average sea-level pressure for the month at a number of land stations on the coast and islands of the North Atlantic. The readings are for 8 a. m., 75th meridian time, and the departures are only approximate, as the normals were taken from the Pilot Chart and are based on Greenwich mean noon observations, which correspond to those taken at 7 a. m., 75th meridian time.

Station	Average pressure	Departure
	Inches	*Inches*
St. Johns, Newfoundland	30.03	+0.03
Nantucket	30.11	+0.07
Hatteras	30.04	+0.01
Key West	29.92	−0.04
New Orleans	29.97	−0.01
Swan Island	29.79	−0.09
Turks Island	29.96	−0.01
Bermuda	30.11	+0.05
Horta, Azores	30.20	+0.03
Lerwick, Shetland Islands	29.64	−0.18
Valencia, Ireland	29.79	−0.20
London	29.86	−0.14

It will be noticed that the average pressure did not differ materially from the normal at the majority of the stations in the above list, although in northern Europe and in the western part of the Caribbean Sea, fairly large negative departures were the rule. At Horta the barometric readings ranged from 29.94 inches on the 2d and 7th to 30.44 inches on the 15th and 30th.

Taking the ocean as a whole, the number of days on which winds of gale force were reported was in excess of the normal as shown on the Pilot Chart. The waters west of the Bermudas were invaded by a succession of tropical disturbances, while gales of extra-tropical origin were unusually frequent over the middle and eastern sections of the steamer lanes.

Fog was not quite as prevalent over the Grand Banks as in August, although the number of days on which it was observed in that region was somewhat above the normal for the current month. Fog was reported on 8 days in the 5-degree square between the 40th and 45th parallels, and the 65th and 70th meridians; it was comparatively rare over the middle and eastern sections of the steamer lanes, and also off the American coast, south of the 40th parallel.

From the 1st to the 4th a tropical disturbance, first reported in August, passed northward over the Bermudas; this is described elsewhere in the REVIEW, but the following storm logs from vessels that were involved may prove of interest:

Spanish S. S. *Sac. 2*, Teneriffe to Tampa:

Gale began on the 2d, wind SE., 8. Lowest barometer 29.04 inches at noon on the 2d, wind SSE., 9, in 26° 39′ N., 66° 13′ W. End on the 2d, wind SW. Highest force of wind 9, SSE.; shifts SSE–SE.

American S. S. *West Camak*, Plymouth to Houston:

Gale began on the 2d, wind SSE. Lowest barometer 29.51 inches at 8 a. m. on the 3d, wind SSW., 11, in 30° 40′ N., 67° 21′ W. End on the 3d, wind WSW. Highest force of wind, 11; shifts SSE–SSW.

French S. S. *Rochambeau*, Havre to New York:

Gale began on the 4th, wind E., 7. Lowest barometer 28.94 inches at 10 a. m. on the 4th, wind NE., 9, in 41° 10′ N., 65° 05′ W. End on the 4th. Highest force of wind 10; shifts E–NE.

On the 1st there was also a LOW in mid-ocean and at the time of observation northerly gales prevailed in the vicinity of 45° N., 40° W., while later in the day southerly winds of gale force were reported from the region between the 55th and 60th parallels and the 20th and 30th meridians. This disturbance moved rapidly northeastward and on the 2d the center was in the vicinity of 57° N., 35° W., with northerly and southerly gales in the western and eastern quadrants, respectively.

A depression first reported on the 4th near 55° N., 35° W., moved slowly eastward and on the 7th was central near 50° N., 20° W.; it reached its greatest intensity on the 5th and strong northerly to northwesterly gales were encountered in the region between the 45th and 50th parallels and the 25th and 40th meridians. Storm log:

Belgian S. S. *Carlier*, Antwerp to New York:

Gale began on the 4th, wind S. 6. Lowest barometer 29.54 inches at 8 a. m. on the 5th, wind NW., 10, in 50° 10′ N., 30° W. End on the 5th, wind NNW., 7. Highest force of wind 10, NNW.; shifts S–SSW–W–NW.

From the 10th until the 24th the waters off the coast of northern Europe were in an almost constant state of turmoil, due to the presence of one cyclonic disturbance after another. On the 10th southwesterly gales were reported from the vicinity of the Scandinavian Peninsula.

Storm log:

American S. S. *Ophis*, Malmo, Sweden, to Charleston:

Gale began on the 10th, wind WNW. Lowest barometer 28.84 inches at 6 a. m. on the 10th, wind SW., in 57° 40′ N., 10° 35′ E. End on the 11th, wind SW. Highest force of wind 10, NW.; shifts WNW–W–NW.

On the 12th westerly gales of hurricane force prevailed over the region between the 25th meridian and the coast of Ireland, as shown by the following storm log.

Norwegian S. S. *Modig*, Androssan, Scotland, to Portland, Me.:

Gale began on the 11th, wind WNW. Lowest barometer 28.98 inches at 4 p. m. on the 12th, wind SW., 11, in 55° 08′ N., 15° 35′ W. End on the 13th, wind WNW. Highest force of wind 12; steady SW.

The daily weather map for September 14 shows a tropical disturbance, described elsewhere in the REVIEW, that moved eastward across Florida and thence northeastward along the American coast. The following storm logs give an idea of its intensity after reaching northern waters.

American S. S. *Steadfast*, Galveston to Liverpool:

Gale began on the 17th, wind S. Lowest barometer 29.74 inches at 4 p. m. on the 17th, wind S., 8, in 37° 49′ N., 66° 32′ W. End on the 18th, wind W. Highest force of wind 8, S.; shifts S–SSW.

British S. S. *Aquitania*, New York to Southampton:

Gale began on the 17th, wind NE. Lowest barometer 29.49 inches at 4 a. m. on the 18th, wind SSW., in 40° 34′ N., 66° 03′ W. End on the 19th, wind W. Highest force of wind 9, SW.; shifts NE–ESE–SSW–SW.

Charts VIII to XIII cover the period from the 16th to 21st, inclusive. In northern waters on the 15th there were two poorly defined depressions; the first central near 50° N., 40° W., and the second in the vicinity of 58° N., 20° W. By the 16th these two areas had apparently joined forces, with the center near 55° N., 20° W., the storm area extending as far west as the 45th meridian. On the 18th this disturbance was off the south coast of Scotland, and had decreased somewhat in extent and intensity.

Storm logs:

Norwegian S. S. *Modig*, Androssan, Scotland, to Portland, Me.:

Gale began on the 15th, wind W. Lowest barometer 29.19 inches at 3 p. m. on the 16th, wind WSW., 11, in 53° 27′ N., 25° 56′ W. End on the 17th, wind WNW. Highest force of wind 12; shifts 8 points.

Danish S. S. *United States*, New York to Kristianssand:

Gale began on the 15th, wind S. Lowest barometer 28.89 inches at 4 a. m. on the 16th, wind WSW., in 56° 14′ N., 24° 15′ W. End on the 19th, wind W. Highest force of wind 10; shifts S. to WSW.

American S. S. *Wildwood*, Aberdeen to Pensacola:

Gale began on the 16th, wind W. Lowest barometer 28.70 inches at 4 p. m. on the 17th, wind W., 9, in 60° N., 9° 30′ W. End on the 18th, wind W. Highest force of wind 9, W.; shifts SSW.-W.-NNW.

Off the south coast of Ireland on the 20th there was a LOW of limited extent, with northwesterly gales in the western quadrants, and southerly in the eastern, as shown by Chart XII.

Storm log:

Dutch S. S. *Veendam*, Rotterdam to New York:

Gale began on the 20th, wind SW. Lowest barometer 29.00 inches at 8 a. m. on the 20th, wind NW., 9, in 49° 50′ N., 17° 44′ W. End on the 20th, wind WNW. Highest force of wind 9, NW.; shifts SW.-NW.

This disturbance moved but little during the next four days, and was intermittent in character, as the force of the wind had decreased by the 21st, only to increase again on the 22d; westerly and northwesterly gales continued until the 24th over the region between the 25th meridian and European coast.

Storm logs:

British S. S. *Masconomo*, Norfolk to Hamburg:

Gale began on the 22d, wind WSW. Lowest barometer 29.71 inches at 7 a. m. on the 22d, wind WSW., in 48° 33′ N., 20° 40′ W. End on the 23d, wind N. Highest force of wind 11, WSW; shifts WSW.-NNW.-NW.

British S. S. *Minnetonka*, Cherbourg to New York:

Gale began on the 22d, wind SSW. Lowest barometer 29.23 inches at 3:50 p. m. on the 22d, wind SW., in 49° 49′ N., 12° W. End on the 24th, wind NW. Highest force of wind 10; shifts SSW.-SW.

From the 24th to the 27th there was an area of low pressure over the region between Newfoundland and the 40th meridian, where a few vessels reported winds of moderate gale force.

From the 28th to 30th the last tropical disturbance of the month, as described elsewhere, moved from the south coast of Cuba on the former date to the vicinity of Hatteras on the latter.

On the 29th northerly winds, force 7, were reported from vessels in the western part of the Gulf of Mexico, and southerly winds, force 8, from off the coast near Nantucket on the 30th.

On the 26th there was a LOW central about 10 degrees east of St. Johns, Newfoundland, that moved slowly northeastward, and on the 27th was near 52° N., 40° W.

Storm log:

Swedish S. S. *Stockholm*, New York to Gothenburg:

Gale began on the 26th, wind NW. Lowest barometer 29.97 inches at noon on the 26th, wind NW., 8, in 48° 04′ N., 50° 32′ W. End on the 27th, wind N. Highest force of wind 8; shifts NW.-NNW.

From the 28th until the 30th there was another disturbance over the region between the 30th meridian and European coast that reached its greatest intensity on the 29th.

Storm log:

British S. S. *Verbania*, New York to London:

Gale began on the 29th, wind W. Lowest barometer 29.66 inches at 6 a. m. on the 29th, wind W., 8, in 48° 55′ N., 25° 20′ W. End on the 29th. Highest force of wind 8, NW.; shifts W.-NW.

NORTH PACIFIC OCEAN

By WILLIS EDWIN HURD

The change from summer to early autumn conditions, although gradual, was none the less decided. Depressions of the temperate regions appeared over somewhat lower latitudes than in August, and the Aleutian cyclone became restored to its place over the northern sailing routes. As a consequence, although the weather continued generally fine, gales in middle and higher latitude became more frequent and cloudiness and rains were common over the northern reaches of the North Pacific. Fog, however, became less prevalent. It was observed on several days both east and west of the 180th meridian, but only along the American coast between the 30th and 50th parallels did it approximate the frequency of its occurrence in August. Between San Francisco and San Diego fog was reported by steamships on 16 days of the month.

The general pressure distribution over the ocean for September showed the great anticyclone of middle latitudes, central near 35° N., 145° W., continuing as a stable condition, but becoming somewhat more disturbed by cyclonic movements with the advance of the season. In the neighborhood of Midway Island two cyclones, one on the 12th and 13th, the other on the 19th and 20th, cut into the high-pressure area from the west. On the north the Aleutian LOW, encroaching southward, distorted the HIGH on several occasions. On the east, while no depression came in from the Hawaiian region, yet low pressure spread westward from the United States on the 11th and 12th and in conjunction with the Gulf of Alaska LOW, covered the whole ocean east of 140° west longitude. Anticyclones entered the United States from the oceanic HIGH on the 1st, 3d, 8th, 16th, 20th, and 25th.

The average pressure at Dutch Harbor, based on p. m. observations, was 29.71, or 0.04 inch below normal. The highest reading, 30.54, was recorded on the 19th and 20th; the lowest, 28.96, on the 25th. At Midway Island pressure was slightly above normal, the average being 30.03 inches, as compared with a normal of 30.01. The highest reading, 30.14, was recorded on the 27th; the lowest, 29.78, on the 18th and 19th. At Honolulu also pressure was above normal, the departure there being relatively greater than at either of the other island stations, +0.05 inch. The average of the p. m. observations was 30.03 inches. September was the second month in succession when pressure at Honolulu did not on any day register below normal at the time of the p. m. observation. The highest pressure, 30.14, occurred on the 5th; the lowest, 29.92, on the 17th.

Frequent rains fell over the northern part of the ocean and along the California-Panama route. In the latter region there seems to have been an unusual amount of precipitation. But at Honolulu the month is mentioned as the third driest September on record, with a total of only 0.34 inch of rain.

At Honolulu, quoting from the observer, "the most important feature of the month was the very small change in average temperature from day to day. The daily change for September averaged only 0.5°, which

is the smallest of any month of record with the exception of July, 1907, when the average was 0.4°." The prevailing wind was from the east, and the maximum velocity was at the rate of 28 miles an hour from the NE. on the 28th.

Vessels at sea reported gales off the west coast of Mexico on the 6th, 7th, and 9th, accompanied in each case by a slight to moderate depression of the barometer and a slight wind shift. On September 6 the American S. S. *Venezuela*, in 20° 50′ N., 107° W., encountered a SE. gale, force 9, pressure 29.87. The American S. S. *Edward Luckenbach*, San Pedro to Panama, experienced a gale from SSE., force 8, in 22° 48′ N., 109° 52′ W., on the 7th. The pressure dropped to 29.64 inches, and on the following day rose to 29.84. On the 9th her observed pressure fell to 29.79 in the course of an east gale, force 8, in 18° 05′ N., 103° 07′ W. In each instance the gale was experienced for about 10 hours.

In connection with these data it is interesting to present herewith two reports for which the Weather Bureau is indebted to Prof. P. Vasquez Schiaffino, chief of the Observatory of Mazatlan. The first of these deals with the tropical storm of September 2–8, which is considered to have originated near 10° N., 98° W., and to have died out near 27° N., 117½° W. The report follows:

The path of this cyclone is similar to that of October 29–November 2, 1920, but the storm was less intense. In 1920 the path recurved to northeast approximately at latitude 25° N., entering the United States in the vicinity of San Diego.

This is the path most frequently followed by cyclones on the western coast of Mexico.

The highest wind velocities are always recorded in the ports to the south of Cape Corrientes when the path takes the present direction, but the swell produced by the storm is very heavy and endangers navigation as far as to the north of Guaymas.

This cyclone produced violent winds from the southeast at Acapulco, Manzanillo, and Maria Madre Island, and strong winds from the same direction at San Blas, Mazatlan, and La Paz, but in none of these ports was there recorded any considerable damage.

The steamer *Chiapas* was overtaken by the storm shortly after its departure from Manzanillo for Mazatlan; it arrived at the latter port on the morning of September 6 after having had to lie off port for 48 hours on account of the heavy swell which prevented entrance to the anchoring ground.

The gunboat *Canonero*, however, was able to anchor at Mazatlan.

Professor Schiaffino's second report, relating to the storm which originated on the 6th near 10° N., 102½° W. and entered the coast between Acapulco and Mazanillo on the 9th, where it was experienced by the *Edward Luckenbach*, is here quoted:

This cyclone followed a somewhat unusual path, since it is very rare for a cyclone from the Pacific to cross the Mexican Republic as this one did. The cyclones that have previously passed to the Gulf of Mexico have crossed the Isthmus of Tehuantepec, but never to the west of the 100th meridian.

Generally, when the direction of the path is like that of the present storm, from southwest to northeast, the cyclone disappears on reaching the land and encountering the foothills of the Sierra Madre and only causes heavy rains and strong winds over a limited area.

This storm gave torrential rains from Acapulco to Mazatlan and copious rains over the greater part of the Mexican Republic. At Acapulco the depth of rainfall was more than 300 mm. (11.80 inches) in 54 hours. At this port the wind attained violent velocities, shifting from northeast to southeast, south, and west. At Mazatlan the wind blew strongly from northwest, shifting to west, and southwest.

On passing to the Gulf of Mexico the storm produced heavy rains and strong winds on the coasts of the States of Tamaulipas and Vera Cruz.

No damage to shipping was reported on the Pacific coast. On the railway in the State of Colima there were numerous washouts due to heavy rains.

Of the two depressions occurring west of Midway Island, that of the 19th is the only one known to have produced gale winds. The American S. S. *Dickenson* reported this, recording a steady south wind for some hours, highest force 8, lowest pressure 29.64, in 28° 20′ N., 176° 10′ W.

At this writing (October 31) the report of typhoons for September has not been received from the Philippine Weather Bureau, but our information points to at least two typhoons in the waters of the Far East. The first seems to have originated west-northwest of Guam on the 1st or 2d and to have moved northwest to the China coast, which it entered on the 7th (local time).

The American S. S. *West Faralon*, Hongkong to San Francisco, came under its influence on the 5th and 6th and changed her course to avoid the approaching center. She was in 27° 30′ N., 123° 40′ E., early on the 6th when her barometer read the lowest, 29.52. The highest wind force was 8, shifting from N. through E. to SE.

The second typhoon affected Japan from the 12th to the 16th. Many parts of the Empire were flooded, owing to the heavy rains. In Tokyo alone 40,000 houses were said to have been partly submerged. A number of casualties resulted from wind and water. In this severe storm the American S. S. *President Lincoln*, Shanghai to Kobe, reported a gale from NE. by E. force 11, in 32° 34′ N., 126° 55′ E. on the 14th. She also encountered a whole NE. gale during much of the 15th, on which date at G. M. N. she was in 32° 59′ N., 127° 21′ E. Her lowest observed pressure was only 29.49 inches. During the 15th and 16th the American S. S. *Wheatland Montana* experienced strong NE. winds in the Japan Sea.

While gales increased in frequency over the northern half of the ocean—and they were reported on 21 days of the month—few of them rose to a strength exceeding force 9. Of these few a WNW. gale, force 10, was observed on the afternoon of the 11th by the American S. S. *Java Arrow*, pressure 29.37, in 46° 17′ N., 149° 09′ W., during a surge of the Aleutian cyclone into the Gulf of Alaska. A westerly gale, force 10, was observed by the American S. S. *President Jackson* on the 24th, in 49° 49′ N., 172° 07′ W., lowest pressure 28.93. This occurred while the Aleutian LOW was at its most intense stage for September, and on this day the lowest observed pressure of the month, 28.64, was recorded at St. Paul, in Bering Sea.

On September 30 three centers of activity lay over the northern part of the ocean east of 180°. One covered a good part of Alaska and Bering Sea, another was central south of Dutch Harbor, and a third was moving into the eastern part of the Gulf of Alaska. The last two caused gales in their respective areas, but the more western, although not especially deep, gave the highest wind force noted outside of the typhoon area. This was recorded by the American S. S. *West Nilus*—N. 11, lowest pressure 29.38—in 44° 16′ N., 170° 41′ W.

CYCLONIC DISTURBANCES IN SOUTHERN OCEANS

By ALBERT J. MCCURDY, JR.

South Pacific Ocean.—Weather reports thus far received from vessels traversing the shipping routes of the South Pacific Ocean in September, 1924, indicate only two disturbances of any consequence.

The first, a northwesterly gale accompanied by high seas, was experienced on the 6th and 7th by the British S. S. *Corinthic*, Capt. Frank Hart, Wellington to Montevideo, while rounding Cape Horn. Mr. F. G. Rogers, fifth officer, reports that the lowest pressure observed

was 29.38 inches (uncorrected), occurring at 7:35 a. m. on the 7th in 55° 51′ S., 66° 12′ W. The wind at the time was NW., force 8.

A report of the second gale was received from the British S. S. *Waikawa*, Suva, Fiji, to Vancouver. The observer, Mr. J. Haultain, states that a fresh gale began on the 12th, accompanied by a heavy confused sea and rain squalls. The lowest barometer recorded was 29.78 inches (uncorrected), this occurring at 3:15 a. m. on the 13th in 13° 37′ S., 177° 5′ W. The wind at this time was ESE., force 8. This gale lasted throughout the evening of the 13th and during that time the wind increased to force 9, with shifts from the SE., ESE., E., and ESE.

South Atlantic Ocean.—Of the cyclonic disturbances occurring in the South Atlantic Ocean during September, only one of any significance has been reported. This was a depression which appeared on the 14th off the coast of Uruguay and which until the 16th occasioned moderate to whole gales with heavy rain squalls and rough seas. The Danish S. S. *Oregon*, Capt. W. Muhldorff, Cardiff to Bahia Blanca, came within its influence on the 14th. Mr. L. Olsen, second officer, reports that the lowest pressure was 29.84 inches, occurring at 4 p. m. on the 15th in 33° 59′ S., 51° 40′ W. The wind which at this time was NNE., force 8, later shifted to E. and increased to force 9–10.

On the 16th the Dutch S. S. *Alchiba*, Capt. K. E. Dik, Rotterdam to Buenos Aires, encountered the same gale in 34° 30′ S., 53° 14′ W., reporting conditions similar to those experienced by the *Oregon*. Mr. J. P. Nieman, observer, states that the lowest barometer, 29.80 inches, was recorded at 8:28 a. m. on the 16th. The wind at this time was NW., force 7–8.

DETAILS OF THE WEATHER IN THE UNITED STATES

GENERAL CONDITIONS

ALFRED J. HENRY

The month may be characterized as cool east of the Rocky Mountains, warm west; heavy rains on the closing days in Atlantic coast districts, severe drought in Louisiana, parts of Texas and Mississippi, and deficient precipitation generally in the Rocky Mountain, and plateau regions, also in California, Nevada, eastern Washington, and eastern Oregon.

The usual details follow:

CYCLONES AND ANTICYCLONES

By W. P. DAY

The month was dominated by high-pressure areas, not of the swiftly moving cool-wave types, but areas of relatively high pressure generally moving in from the Pacific, becoming greatly enlarged and very persistent through frequent reinforcement from the Canadian interior. This condition was most noticeable during the second and third decades and the movement of LOWS was affected by it. That is, the polar-equatorial interchange of air was more north-south, the HIGHS being so frequently revived that they interfered with the normal easterly drift and the warm air of the Tropics moved northward between such high pressure systems in troughs or in more temporary formations of a definite cyclonic nature.

Two fully developed hurricanes were charted during the month. The first had been followed during the last days of August as it passed northwestward over the Leeward and Virgin Islands, but was not definitely located again until the 2d of September when it was about 400 miles southwest of Bermuda. Lack of reports again prevented a full knowledge of its movements until it reached the steamer lanes south of Halifax on the morning of the 4th and the south coast of Newfoundland the same evening. The second hurricane developed over the eastern portion of the Gulf of Mexico and had attained considerable intensity when it struck a small section of the Florida coast near Appalachicola.

FREE-AIR SUMMARY

By L. T. SAMUELS, Assistant Meteorologist

It is found from kite observations that the negative temperature departures at the surface for the month over the country east of the Rocky Mountains either decreased in magnitude or changed to positive with increase in elevation above the ground. The northern and eastern stations showed the strongest tendency toward maintaining relatively low mean temperatures in the upper levels. Notwithstanding this fact, the resultant winds for the month as determined from kite observations at Ellendale and Royal Center, two of the stations referred to above, had a larger southerly component and at Due West a smaller northerly component than the normal. This appears paradoxical unless we consider the relatively small resultant velocities usually obtained during a month where the ordinary procession of HIGHS and LOWS causes a continuous succession of northerly and southerly winds. As a rule the resultant winds for a month as determined from pilot-balloon observations agree closely with those found by kites. However, when the observations are not similarly distributed, as occurred this month at Due West, large differences are frequently found. For example, at the 1,500-m. level at this station the resultant wind determined from pilot-balloon observations was N. 73° W. 3.8, whereas that from kite observations was S. 84° E. 3.2, almost diametrically opposite, and yet of significant velocities. The cause of this difference is at once apparent when we learn that balloon and kite observations were possible on the same day only five times during the month, weather conditions prohibiting either one or the other or both on the remaining days.

The effects of the increasingly longer nights, especially at the more northern stations, become apparent at this season of the year in the temperature lapse-rates above the earth's surface. It is interesting to note the lati-

tudinal variations in the normal lapse-rates for September for the first 1,000 m. above the ground.

Station	Decrease in temperature (°C.) from surface to 1,000 m.
Ellendale	3.3
Drexel	4.3
Broken Arrow	5.6
Groesbeck	6.7
Royal Center	7.0
Due West	6.9

The consistent increase with decreasing latitude is clearly brought out in these figures, as are the comparatively large lapse-rates for the two eastern stations. The cause of the latter is to be found in a combination of factors, such as the later average hour of making kite flights, the warming effect produced in the lower levels of HIGHS before reaching these stations, the different source of the southerly air in a LOW at these stations from that of the western stations, etc.

In general, the relative humidity departures for the month were of opposite sign with respect to those for temperature and vapor pressure, as is usually found. (See Table 1.)

The high pressure area central over the middle of the country on the 29th brought the lowest temperatures for the month at Ellendale and Drexel on that date, and on the 30th at the other four stations. These abnormally low temperatures extended to considerable heights at all six stations, breaking previous minimum temperature records for October at various altitudes reached by the kites at Broken Arrow, Due West, Groesbeck, and Royal Center.

Fortunately there was obtained simultaneously at Ellendale and Royal Center a series of kite flights extending at the former station from 7:13 a. m. September 30 to 11:44 a. m. October 1 and from 7:19 a. m. September 30 to 10:30 a. m. October 1 at the latter station. During the course of this series Royal Center experienced the passage of the center of an elongated HIGH while Ellendale was in the path of an approaching LOW.

An examination of the first flight at Royal Center reveals a vertical temperature gradient for the first 1,000 m. exceeding the adiabatic rate for dry air. The wind was from the north and there were two-tenths A. St. clouds when the flight was started. Owing to this strong vertical temperature gradient the sky became nearly overcast with St. Cu. clouds within two hours, the tops of which coincided with the bottom of the inversion layer. The wind remained north throughout the inversion. The clouds were at first shallow but thickened steadily from 250 m. to 1,200 m. by 5 p. m. It is interesting to note the coincident thickening of the cloud layer with the increasing elevation of the inversion, the tops of the clouds always reaching to the beginning of the inversion. A trace of rain fell at Royal Center when this cloud reached its maximum thickness. By 8 p. m. the HIGH had moved southward and was central over the lower Mississippi Valley. At this time the surface wind at Royal Center became WSW. and the upper winds WNW. and NW. A tremendous warming aloft occurred with the arrival of this westerly air and indicated plainly its totally different origin. The greatly increased temperatures found above the surface, and the time interval between the observations are shown in the following table, which represents the descent of the third flight and the ascent of the fourth.

Altitude (m.) M. S. L.	Temperature change (°C.)	Time interval between observations (hrs.)
225 (surface)	−1.5	4
500	+1.9	4
1,000	+1.9	5
1,500	+3.8	7
2,000	+7.9	7
2,243	+8.8	7

The time intervals are those necessitated in making the flights, but it is reasonably certain that the actual time required for the changes was even less than that shown in the table. Such large temperature changes in the short intervals at these elevations are of great significance in the consideration of air trajectories. The fact that a south component is not always necessary for an appreciable rise in temperature is in this case well demonstrated. The cloud layer referred to above was quickly dispelled by the invasion of this warmer air and the sky remained cloudless for several hours when a few Ci. and Ci. St. appeared from the west.

At Ellendale where a series was made during this same period the conditions were of course totally different. This station was in the rear of the HIGH and experienced conditions incident to the approaching LOW, although the center of the latter had not reached Ellendale by the end of the series. The surface winds here remained practically south during the series while the upper winds backed from WNW. at the beginning to WSW., at the end of the series. The temperature rose, level for level, during the series, above the heights to which the nocturnal inversions extended.

The relative humidity throughout the series decreased with elevation, being around 30 per cent at the highest levels (4,000 m.). This is characteristic of LOWS in this region where the absolute humidity of the relatively warm air is low and therefore clouds of the lower type are usually absent.

An interesting occurrence showing the extensive proportions of relatively thin air currents occasionally found was revealed in kite records of the 18th from Ellendale, Drexel, and Broken Arrow, a flight at Groesbeck being prevented by rain and light wind. On this date the stations named above were within a region of nearly straight N-S. isobars between an ill-defined HIGH central over the Great Lakes and an elongated LOW central over the eastern slope of the Rocky Mountains. The winds at Ellendale were SSE. to the highest levels reached (3,010 m.), at Drexel SSE. veering to SW. at the highest level (3,655 m.), and at Broken Arrow SE. veering to SW. at the highest level (3,678 m.). At about the 2,500-m. level there was found at all three stations a sharply defined layer of warm air causing a pronounced inversion.

Within this warm current the relative humidity dropped from saturation to 34 per cent at Ellendale, 22 per cent at Drexel, and 43 per cent at Broken Arrow. Following are the data showing the thickness of this layer and the temperature differences found at its upper and lower boundaries at each of the stations.

Station	Altitude (m.) of lower boundary and temperature (°C.)	Altitude (m.) of upper boundary and temperature (°C.)
Ellendale	2,296 2.1	2,524 5.8
Drexel	2,652 −1.4	2,724 4.6
Broken Arrow	2,252 6.6	2,496 12.3

The records from Royal Center on the 28th and 29th afford an excellent example of a slow-moving wedge of cold northerly air underrunning a rapidly moving current from the south. The following table gives the temperatures and winds at Royal Center on these dates.

Altitude M. S. L.	Temperature (°C.) 28th	Temperature (°C.) 29th	Wind 28th	Wind 29th
225 *meters* (surface)	10.3	6.8	NW.	N.
1,000	5.1	2.7	WNW.	NNE.
1,500	4.5	−0.7	WSW.	N.
2,000	4.0	−2.0	WSW.	NNW.
2,500	3.2	−3.0	WSW.	N.
3,000	5.1		SW.	W.
3,500	1.4		SSW.	WSW.

The progressively increasing height of the northerly current is clearly shown and while the kite and balloon observations did not extend higher than indicated in the above table, there were observed on the 29th 6/10 A Cu clouds moving from the SE. That this upper southerly current was comparatively warm is revealed in the above listed temperatures of the 28th, which show that the temperature at 3,000 m. was the same as that at 1,000 m. Such a stable condition was, of course, not conducive to rain.

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during September, 1924*

TEMPERATURE (°*C.*)

Altitude m. s. l. (*m.*)	Broken Arrow, Okla. (233 *m.*) Mean	Departure from 7-yr. mean	Drexel, Nebr. (396 *m.*) Mean	Departure from 9-yr. mean	Due West, S. C. (217 *m.*) Mean	Departure from 4-yr. mean	Ellendale, N. Dak. (444 *m.*) Mean	Departure from 7-yr. mean	Groesbeck, Tex. (141 *m.*) Mean	Departure from 6-yr. mean	Royal Center, Ind. (225 *m.*) Mean	Departure from 7-yr. mean
Surface	20.4	−2.7	16.4	−2.1	20.3	−2.8	12.6	−2.1	22.0	−2.3	17.1	−3.9
250	20.3	−2.6			19.7	−3.0			21.7	−2.0	16.8	−4.0
500	18.7	−2.6	16.0	−2.1	17.3	−2.9	12.5	−2.2	21.1	−1.2	14.3	−4.2
750	17.4	−2.6	14.5	−2.5	15.5	−2.9	11.8	−2.3	20.0	−0.9	12.5	−4.3
1,000	16.3	−2.4	13.2	−2.8	14.6	−2.6	11.2	−2.0	18.8	−0.9	10.8	−4.4
1,250	15.6	−1.8	12.3	−2.6	13.8	−2.3	10.7	−1.6	17.8	−0.6	9.2	−4.5
1,500	14.9	−1.2	11.2	−2.5	12.8	−2.0	9.5	−1.7	16.9	−0.4	7.7	−4.5
2,000	13.3	−0.3	9.6	−1.5	10.3	−1.9	6.5	−2.1	15.3	+0.3	5.6	−4.0
2,500	11.1	+0.3	7.2	−0.8	7.6	−1.7	3.9	−1.8	13.4	+0.9	2.9	−4.1
3,000	8.7	+0.8	5.2	+0.2	5.0	−1.5	1.5	−1.3	11.9	+1.9	2.2	−2.4
3,500	5.6	+0.9	2.5	+0.4	2.2	−1.5	−1.2	−1.3	9.8	+2.3	−0.6	−2.6
4,000	1.9	+0.3	0.1	+0.8	−2.3	−2.2	−3.8	−1.3	7.0	+2.3		
4,500	−1.2	0.0	−2.3	+1.3	−4.9	−1.4			4.2	+2.2		
5,000									1.3	+1.5		

RELATIVE HUMIDITY (%)

Altitude m. s. l. (*m.*)	Broken Arrow Mean	Departure	Drexel Mean	Departure	Due West Mean	Departure	Ellendale Mean	Departure	Groesbeck Mean	Departure	Royal Center Mean	Departure
Surface	68	0	66	+1	72	+6	71	+5	72	−4	70	+5
250	68	0			73	+7			69	−7	70	+5
500	66	0	63	0	75	+5	70	+5	64	−11	70	+5
750	64	0	62	+2	76	+4	66	+4	64	−11	71	+6
1,000	63	0	62	+4	75	+4	64	+4	61	−11	73	+8
1,250	59	−3	59	+3	75	+6	61	+4	57	−13	76	+11
1,500	54	−5	59	+4	81	+11	61	+6	51	−16	77	+13
2,000	45	−9	56	+3	79	+14	65	+13	47	−15	60	+1
2,500	43	−7	58	+4	82	+17	61	+10	44	−12	56	+1
3,000	42	−7	49	−4	84	+22	57	+6	35	−17	50	−1
3,500	44	−8	45	−6	87	+27	53	+4	32	−17	52	+4
4,000	50	0	44	−6	89	+22	54	+8	28	−18		
4,500	49	0	42	−9	88	+21			26	−20		
5,000									25	−19		

VAPOR PRESSURE (mb.)

Altitude m. s. l. (*m.*)	Broken Arrow Mean	Departure	Drexel Mean	Departure	Due West Mean	Departure	Ellendale Mean	Departure	Groesbeck Mean	Departure	Royal Center Mean	Departure
Surface	16.09	−3.06	12.30	−1.78	17.16	−1.51	10.21	−0.89	19.38	−3.65	13.85	−2.37
250	15.97	−3.05			16.87	−1.57			18.44	−3.78	13.62	−2.39
500	14.23	−2.77	11.63	−1.82	14.94	−1.92	9.98	−0.94	16.49	−3.77	11.77	−2.44
750	12.67	−2.58	10.44	−1.61	13.64	−1.92	8.96	−1.02	15.21	−3.22	10.58	−2.27
1,000	11.71	−2.21	9.51	−1.41	12.81	−1.51	8.13	−0.91	13.71	−2.70	9.74	−1.95
1,250	10.66	−1.92	8.51	−1.30	12.07	−0.92	7.40	−0.67	12.15	−2.61	9.02	−1.51
1,500	9.29	−1.78	7.83	−1.07	11.84	−0.17	6.86	−0.42	10.34	−2.73	8.29	−1.14
2,000	6.91	−1.50	6.35	−0.91	9.70	+0.03	6.02	+0.12	8.41	−1.85	5.73	−1.52
2,500	5.60	−0.65	5.35	−0.68	8.26	+0.23	4.73	−0.17	7.04	−0.88	4.29	−1.18
3,000	4.50	−0.32	4.05	−0.88	6.93	+0.28	3.71	−0.46	5.27	−0.97	3.13	−0.85
3,500	3.72	−0.34	3.20	−0.78	6.52	+0.71	2.95	−0.55	4.47	−0.63	2.23	−0.70
4,000	3.32	+0.26	2.73	−0.60	6.05	+0.59	2.63	−0.30	3.65	−0.44		
4,500	3.10	+0.64	2.26	−0.56	5.64	+0.62			3.11	−0.44		
5,000									2.97	−0.16		

TABLE 2.—*Free-air resultant winds (m. p. s.) during September, 1924*

Altitude, m. s. l. (*meters*)	Broken Arrow, Okla. (233 meters) Mean Dir.	Mean Vel.	7-year mean Dir.	7-year mean Vel.	Drexel, Nebr. (396 meters) Mean Dir.	Mean Vel.	9-year mean Dir.	9-year mean Vel.	Due West, S. C. (217 meters) Mean Dir.	Mean Vel.	4-year mean Dir.	4-year mean Vel.
Surface	S. 56°E.	1.4	S. 2°E.	3.1	S. 29°E.	1.0	S. 10°W.	1.7	N. 55°E.	3.7	N. 62°E.	2.7
250	S. 56°E.	1.5	S. 2°E.	3.2					N. 60°E.	3.8	N. 62°E.	2.6
500	S. 47°E.	2.0	S. 6°W.	4.4	S. 29°E.	2.1	S. 8°W.	2.4	N. 52°E.	3.9	N. 57°E.	2.8
750	S. 38°E.	2.3	S. 13°W.	5.0	S. 1°E.	3.6	S. 22°W.	3.7	N. 72°E.	6.5	N. 64°E.	3.5
1,000	S. 6°E.	1.2	S. 24°W.	4.7	S. 1°W.	4.0	S. 31°W.	4.0	N. 84°E.	6.2	N. 69°E.	3.3
1,250	S. 63°W.	1.4	S. 31°W.	4.7	S. 31°W.	4.3	S. 47°W.	4.3	N. 68°E.	5.3	N. 52°E.	3.3
1,500	S. 86°W.	2.5	S. 42°W.	4.8	S. 41°W.	5.7	S. 58°W.	4.9	S. 84°E.	3.2	N. 54°E.	2.5
2,000	S. 88°W.	4.8	S. 51°W.	5.6	S. 79°W.	5.8	S. 70°W.	5.8	S. 69°E.	3.4	N. 56°E.	1.8
2,500	S. 85°W.	6.3	S. 61°W.	5.2	S. 85°W.	6.7	S. 77°W.	7.4	S. 47°E.	2.8	N. 55°E.	1.2
3,000	N. 87°W.	6.8	S. 54°W.	6.0	S. 86°W.	9.3	S. 83°W.	9.3	S. 64°W.	6.2	N. 35°W.	0.2
3,500	S. 85°W.	8.5	S. 62°W.	5.8	N. 88°W.	12.3	N. 88°W.	10.7	N. 86°W.	11.4	N. 34°W.	2.0
4,000	N. 78°W.	13.0	S. 81°W.	8.0	N. 83°W.	11.7	N. 77°W.	12.0	N. 86°W.	11.4	N. 24°W.	2.0
4,500	N. 77°W.	16.3	N. 64°W.	11.5	S. 86°W.	9.2	N. 71°W.	12.9	N. 67°W.	13.0	N. 11°W.	7.3
5,000									N. 67°W.	11.5	N. 3°W.	7.1

Altitude, m. s. l. (*meters*)	Ellendale, N. Dak. (444 meters) Mean Dir.	Mean Vel.	7-year mean Dir.	7-year mean Vel.	Groesbeck, Tex. (141 meters) Mean Dir.	Mean Vel.	6-year mean Dir.	6-year mean Vel.	Royal Center, Ind. (225 meters) Mean Dir.	Mean Vel.	7-year mean Dir.	7-year mean Vel.
Surface	S. 40°W.	1.1	N. 1°W.	0.8	N. 89°E.	0.8	S. 27°E.	1.7	S. 39°W.	0.2	S. 54°W.	1.4
250					S. 69°E.	0.9	S. 24°E.	2.4	S. 26°W.	0.4	S. 50°W.	1.6
500	S. 35°W.	1.4	S. 77°W.	0.9	S. 19°E.	1.5	S. 14°E.	3.7	S. 30°W.	2.7	S. 47°W.	3.2
750	S. 32°W.	3.0	S. 60°W.	1.8	S. 3°E.	1.8	S. 8°E.	4.0	S. 43°W.	4.2	S. 56°W.	4.2
1,000	S. 32°W.	3.6	S. 64°W.	2.6	S. 5°W.	2.2	S. 7°E.	4.2	S. 54°W.	4.5	S. 64°W.	4.8
1,250	S. 38°W.	3.1	S. 68°W.	3.0	S. 4°W.	1.9	S. 7°E.	4.2	S. 59°W.	6.0	S. 68°W.	6.0
1,500	S. 44°W.	3.0	S. 76°W.	3.7	S. 19°W.	1.3	S. 6°E.	4.0	S. 70°W.	5.8	S. 73°W.	6.4
2,000	S. 58°W.	2.6	S. 79°W.	4.9	S. 62°W.	0.9	S. 3°E.	3.5	S. 75°W.	4.6	S. 74°W.	8.2
2,500	S. 80°W.	3.5	S. 85°W.	6.8	N. 42°W.	1.8	S. 6°E.	3.4	S. 40°W.	5.8	S. 74°W.	9.6
3,000	N. 73°W.	4.9	W.	8.6	N. 37°W.	1.9	S. 6°E.	3.4	S. 23°W.	13.5	S. 70°W.	12.4
3,500	N. 50°W.	7.2	N. 89°W.	10.0	N. 6°W.	3.0	S. 2°E.	2.7	S. 12°W.	17.8	S. 78°W.	12.3
4,000	N. 30°W.	8.5	N. 75°W.	11.7	N. 2°E.	3.7	S. 4°E.	2.7				
4,500	S. 23°W.	13.9	N. 73°W.	12.8	N. 10°E.	1.2	S. 1°E.	4.4				
5,000					S.	1.7	S. 24°E.	4.4				

THE WEATHER ELEMENTS

By P. C. DAY, Meteorologist, in Charge of Division

PRESSURE AND WINDS

The atmospheric circulation during September, 1924, became more active than had been the case for several preceding months, and, as is to be expected, with the beginning of autumn. This was particularly the case over the southeastern districts, which were more or less affected by two tropical storms that passed over the Florida Peninsula and moved northeastward along the Atlantic coast; a third, threatening the southeastern districts at the beginning of the month, moved northeastward between the Bermuda Islands and the Atlantic coast, giving high winds over portions of the trans-Atlantic steamship routes.

Except as indicated above, the cyclonic storms were mainly without importance, although on the 1st and 2d a low-pressure area moving from the southern Plains to the middle Atlantic coast brought general rains, heavy in a few localities, over most districts from the eastern Plains to the Atlantic coast. Also from the 8th to 10th a disturbance of moderate intensity brought general rains from the lower Missouri and upper Mississippi Valleys eastward and southeastward to the Atlantic coast, the falls becoming heavy along the coast from Chesapeake Bay to Maine.

More or less rain occurred from the 11th to the 13th over the central valleys and Great Lakes region, attending the progress of a slight barometric depression moving from the southern Plains to the northward of Lake Superior.

The tropical disturbance which approached the west Florida coast on the morning of the 14th crossed the northern portion of that State and moved northeastward along the Atlantic coast during the following few days. It was attended by some extraordinarily heavy rains in portions of the southeastern States, notably in western Florida, where from 10 to nearly 15 inches fell during the storm. A full report of this storm will be found elsewhere in this issue.

An important rain area developed over the southern Plains about the 18th and moved to the vicinity of Lake Michigan by the morning of the 20th, attended by rather general rains over the central valleys. This was immediately followed by another pursuing a similar course, and developing considerable energy as it approached the upper Lakes. This storm gave wide precipitation over the central valleys and eastern districts, with heavy falls from the lower Mississippi Valley northeastward to the Great Lakes.

Following the tropical storm over the southeastern States near the middle of the month, rainy conditions persisted over much of this district during the remainder of the month, particularly in Georgia, the Carolinas, and near-by portions of adjacent States.

The last important storm of the month over the interior districts had its origin in the central Rocky Mountains about the middle of the third decade, though little rainfall occurred until about the 27th, when it had overspread much of the Great Plains. By the 28th this rainy condition extended into the Mississippi Valley and Gulf States, and during the following 24 hours into the Atlantic coast districts, where rains became heavy to excessive. At the same time another tropical disturbance had developed in the east Gulf and moved over northern Florida during the night of the 29th, and northeastward along the Atlantic coast on the 30th. This storm was attended by unusually heavy rains over western and northern Florida, southern Georgia, and generally over the Atlantic Coast States, northward to New York. A full account of it and the attending floods also appears elsewhere in this issue.

Anticyclonic conditions prevailed frequently over the interior and northeastern portions of the country, particularly in the last-named district, where they dominated the weather during the greater part of the latter half of the month.

The average pressure for the month was above normal over the interior and northeastern portions of the country, and decidedly higher than in the preceding month over nearly all parts of the United States as well as over Canada, only small areas along the Gulf and Pacific coasts having averages less than in August.

The low pressures attending the two tropical storms which passed over the Southeastern States caused monthly averages less than normal in that region, and the averages over the Pacific Coast States and in the western Canadian Provinces were likewise less than normal.

Wind velocities were mainly not high over extensive areas, save in portions of Wisconsin on the 21st in connection with a series of tornadoes. These caused much property damage and considerable loss of life, details of which appear in the table of severe storms at the end of this section. High velocities occurred along the Atlantic coast in connection with the two tropical storms. Other high winds were mainly associated with local thunderstorms.

TEMPERATURE

The feature of the weather for September showing the most notable departure from usual conditions was the persistent coolness over all central and eastern portions. This was the more notable because it represented a continuance of conditions that had prevailed over much of that territory for many preceding months.

The low averages were mainly the result of continued cool weather, as notable coolness occurred on only a few dates, and daily changes were mainly small.

The first important cold spell, threatening frost, followed the cyclonic storm which moved northeastward to the upper Lakes on the 21st, when high pressure following the storm brought sharp falls of 20° to 30° in temperature over large portions of the central valleys, while frost more or less severe occurred in the northern portions of the Rocky Mountain regions and adjacent portions of the Great Plains. Following this no important frosts occurred until near the end of the month when an anticyclone of wide extent overspread the central valleys, producing conditions favorable for high night radiation, and caused heavy to killing frosts generally from the Missouri Valley to the Great Lakes, and lighter frosts, occasionally killing, considerably farther south.

The main warm periods of the month were during the early portions, notably on the 1st, over practically all sections from the Mississippi Valley eastward; on the 3d and 4th from the Dakotas westward and southwestward; and in portions of the middle and southern Great Plains on the 6th to 8th.

In parts of Montana the maxim m temperatures of the 4th were the highest ever observed so late in the season. In the Great Plains maximum temperatures

for the month were mainly above 100°, and they were as high, and locally higher, in most of the States from the Rocky Mountains westward; also over the Gulf and Atlantic Coast States as far north as Maryland.

The dates of the lowest temperatures were widely scattered, though they occurred mainly toward the latter part of the month. Freezing temperatures were reported from practically all northern and central States, though often these were largely local, due to elevation or to conditions favorable for night radiation. The lowest observed, 5°, was reported from a point in the mountains of Idaho, while in Florida the lowest reported was 43°.

The mean temperature for the month was below normal in all parts of the country from the Rocky Mountains eastward, save along the immediate Gulf coast. Over the central valleys and thence eastward to the Atlantic coast the month as a whole was among the coldest of record for September; in fact at a few points it was the coldest, while over large portions of the Mississippi Valley and to the eastward, with the exception of 1918, it was the coldest September in 50 years. West of the Rocky Mountains the monthly averages were above normal save along the immediate Pacific coast, while in the Canadian Northwestern Provinces, particularly over the more northern districts from which records are available, the month was decidedly warm.

PRECIPITATION

Second among the unusual weather conditions of the month stands out the excessive precipitation that occurred over portions of the Southeastern States during the passage of the two tropical storms over that region. At Apalachicola, Fla., a total of 27.73 inches was recorded, the greater part of which occurred in connection with the two storms referred to above. In a period of slightly more than 38 hours on the 13th to 15th there was a fall of 14.25 inches, while in slightly less than 28 hours on the 28th and 29th, a total of 9.53 inches occurred.

Precipitation nearly as great as that noted in Florida occurred over much of Georgia and the Carolinas, and to a lesser degree to the northward as far as Maryland and Pennsylvania. Over many portions of this area the monthly precipitation was the greatest ever measured in September, and in some localities it was the greatest reported in any month of record.

In striking contrast with the heavy precipitation over the Southeastern States may be mentioned the nearly complete absence of precipitation in portions of Texas, particularly in the vicinity of Galveston, and over much of Louisiana, which, as a whole, had the driest September of record. At Galveston the precipitation was the least for September in more than 50 years, and as practically no precipitation had occurred there during July and less than half an inch in August, the total deficiency for the three months, July to September, amounts to nearly 15 inches.

Dry weather continued over most districts west of the Rocky Mountains, particularly in California and Nevada, where drought conditions have persisted almost generally for a year or more.

The fire hazard in most of the western forest reserves abated little if any during the month and further damage occurred.

Over the western portions of Oregon and Washington there was slightly more precipitation than usually occurs in September.

In general, precipitation was above the normal from the Ohio Valley northeastward, eastward and southeastward to the Atlantic coast, the excesses becoming larger as a rule toward the coast. There was a moderate excess from the Dakotas eastward to Lake Superior, and locally over a narrow area from Missouri and eastern Kansas southwestward to the Rio Grande, also over small areas in western Nebraska, western Kansas, and the adjacent portions of Colorado and Wyoming, and in northern Arizona. Elsewhere precipitation was mainly less than average, though the deficiencies were small.

SNOWFALL

Measurable amounts of snow were reported from high elevations in the western mountain districts, the greatest fall reported being 14 inches, at a point in Colorado. Slight falls were reported from the mountains of northern New York and locally in North Dakota and other northern States.

HUMIDITY AND SUNSHINE

The relative amounts of moisture in the atmosphere varied generally with the precipitation, but the ranges were mainly small, except in the districts west of the Rocky Mountains where the deficiencies ranged up to nearly 15 per cent. There were similar deficiencies in the west Gulf States and westward to New Mexico.

There was much sunshine in the Southwest, notably in Arizona where the last 15 days were practically cloudless and in the Great Valley of California where there was nearly constant sunshine, which greatly advanced the drying of fruits. In other districts west of the Mississippi River there was mainly abundant sunshine. East of the Mississippi more cloudy weather occurred, particularly over the Middle and South Atlantic States where the latter part of the month had much cloudy, rainy weather.

SEVERE LOCAL HAIL AND WIND STORMS, SEPTEMBER, 1924

(The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A more complete statement will appear in the Annual Report of the Chief of Bureau)

Place	Date	Time	Width of path [1]	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Northwest Lafayette and southwest Iowa Counties, Wis.	4	10-11 a.m.				Heavy hail	Extensive damage to crops, principally corn	Official, U. S. Weather Bureau.
New York, N. Y.	5	2:15-2:19 p. m.		1		Waterspout, preceded and followed by electrical display.	Deck cargo of steamer washed overboard; a man killed by lightning.	Official, U. S. Weather Bureau; Times (New York).
Wichita, Kans. (and vicinity)	7	4-5 p. m.	2-4 mi		$4,000	Hail and wind	Damage chiefly to apples and truck	Official, U. S. Weather Bureau.
Norwich (near), Kans.	7	4 p. m.				Violent wind	Outbuildings and windmills damaged	Do.
Deer Lodge, Mont. (4 miles north of).	8					do	Pump house damaged	Do.
Central and eastern counties, Tennessee	8			1		Wind, hail, and electrical.	Trees blown down, barns unroofed, telephone and electric service crippled; corn, tobacco and fodder damaged by hail.	Do.
Bastrop, La. (few miles west of).	8		880		10,000	Thunder and wind squall.	A number of buildings, mostly barns and cabins, blown down; cotton damaged.	Do.
Hartwick, N. Y.	9					Severe wind	Small buildings moved; trees wrecked; minor damage.	Do.
Pebble, Idaho (east of)	9		3,520			Hail	Crops considerably damaged	Do.
Clifton (near), Colo	10	7-8 p. m.	1,760		75,000	do	Loss principally to crops, especially apples	Do.
Marion, Kans	10	P. m.	880		25,000	Tornado	Barns and outbuildings damaged	Do.
South-central Iowa	11					Wind	Farm buildings and corn damaged, straw and hay stacks scattered.	Do.
Downing, Mo	12	7:30 p. m.				Violent wind	Communication wires and trees considerably damaged.	Do.
East Gulf and South Atlantic coasts.	14-16			1		Tropical winds and rains.	Heavy damage on coast and inland. Turpentine orchards and timber suffer considerably; shipping delayed; serious railroad washouts; wire systems wrecked; pecan, cotton, and other crops badly damaged. Southern Georgia hard hit.	Official, U. S. Weather Bureau; Florida-Times Union (Jacksonville, Fla.)
Douglas County, Kans., (southern part of).	15	2 a. m.				Violent wind	Small structures damaged	Official, U. S. Weather Bureau.
Chase County, Kans	15	3:30 p. m.	4-6 mi			Hail	Cane, kafir, and alfalfa injured; autos damaged	Do.
Douglas County Kans., (central part of).	15	5 p. m.	8-10 mi		5,000	do	Corn and rough feed crops damaged	Do.
Butler County, Kans	15	6:15 p. m.	3,520		1,000	Violent wind	Oil rigs and trees damaged, one person injured	Do.
Boone County, Nebr. (Northeast part of).	15	9 a. m.	6 mi			Hail	30 per cent of corn crop damaged	Do.
Brownsville, Ga	16			1	5,000	Probably tornado	Practically all buildings destroyed. Several persons injured.	Do.
Cameron, Mo. (8 miles southeast of).	18	5:30 p. m.			8,000	Thunderstorm	Barn struck by lightning, 1 horse killed, 6 injured; hay, wheat and farm machinery destroyed.	Do.
Reynolds and Iron Counties, Mo.	19	6 p. m.			30,000	Tornadic wind	Greatest damage at Annapolis; 30 to 40 houses were partially wrecked.	Do.
Hot Springs, Ark	19	3:30 p. m.			100,000	Small tornado	Eastman Hotel partly unroofed; church and some smaller buildings destroyed; many trees uprooted.	Do.
Lawrence County, Ark. (southern part of).	19					Wind	Houses, barns, and growing crops damaged	Do.
Evansville, Ind	19	2 a. m.				Wind and rain	Big tent destroyed, streets and cellars flooded, trees torn, electric and power systems crippled.	Official, U. S. Weather Bureau; Press (Evansville, Ind.).
Watts (near), Okla	19	4:15 p. m.			8,000	Wind	One person slightly injured; some property and crop damaged.	Official, U. S. Weather Bureau.
Michigan	20-22			33		Severe wind and electrical.	Shipping hampered; trees and awnings blown down; buildings struck by lightning. Steamer *Clifton* sank off Saginaw Bay, causing loss of 30 lives; 1 life lost in Grand Rapids, 2 in Hart.	Official, U. S. Weather Bureau; Grand Rapids Herald (Mich.).
Wisconsin	21					Wind	Entire State affected; at Milwaukee trees and wires were blown down, windows broken, yacht sunk in harbor.	Official, U. S. Weather Bureau.
Barron to Ashland Counties, Wis.	21	2-5:30 p. m.	70-1,000	10	250,000	Tornado	Houses and buildings wrecked; livestock killed. Path 90 miles long.	Do.
Minocqua, Wis	21	4 p. m.				Probably tornado	Destruction, but details not reported	Do.
Eau Claire to Oneida Counties, Wis.	21	2:20-4:30 p. m.	70-1,000	26	564,000	Tornado	Buildings destroyed, farm animals killed. Path 120 miles long.	Do.
Antigo, Wis	21		4,000			Probably tornado	Details of damage not reported	Do.
Minnesota	21			3		High winds	Many trees blown down, communication and power lines damaged.	Herald (Chippewa Falls, Wis.); Indianapolis Times (Ind.).
Julesburg, Colo	21	9:30 p. m.			10,000	Hail	Sugar beets and corn fodder damaged over a path 40 miles long.	Official, U. S. Weather Bureau.
East Gulf and Atlantic seaboard.	29-30					High winds and rain.	Extensive damage by flooding; bathhouses at Rockaway, N. Y., wrecked; windows broken, trees uprooted; shipping delayed; small boats demolished. Several deaths reported. Much damage to property and crops inland.	Official, U. S. Weather Bureau; Herald Tribune (N. Y.); Washington Post (D. C.).

[1] Yards when not otherwise specified. "mi" signifies miles.

STORMS AND WEATHER WARNINGS

WASHINGTON FORECAST DISTRICT

The month was characterized by considerable activity in the Tropics, in that three disturbances occurred. The first, which appeared on August 28 in the vicinity of Dominica and continued into September, was of major importance. The other two, which developed over the southeastern Gulf of Mexico on the 13th and 28th, were of lesser intensity.

A tropical disturbance at the beginning of the month was central about latitude 25° N. and longitude 70° W. The history and subsequent movement of this disturbance is discussed in the MONTHLY WEATHER REVIEW for August.

Later information which has just come to hand indicates that the center of this storm passed between Antigua and Montserrat (Lesser Antilles) at 3:30 a. m. of the 28th. At 2 a. m. of the 29th the center with a reading of 28.56 inches passed over the eastern end of the island of St. John. The western end of the island of Tortola experienced hurricane winds from 6 p. m. of the 28th to 6 a. m. of the 29th. The storm was accompanied by torrential rains and by winds estimated about 100 to 110 miles an hour. The rains of the 28th and 29th at St. Kitts, 17 inches, and Nevis, 20 inches, are reported to be the heaviest recorded in 40 years. More than 100 lives were reported lost and more than 1,000 houses destroyed, while serious damage resulted to crops along the path of the storm from Montserrat to St. Thomas. The observer at St. Thomas estimated the wind at 110 miles per hour from the north-northeast between midnight and 2 a. m. of the 29th. Estimates of 100 to 110 miles per hour were also made at Montserrat and Antigua between 3 a. m. and 4 a. m. of the 28th.

In connection with a disturbance over eastern Quebec on the 5th, northwest storm warnings were ordered for the Atlantic coast from Sandy Hook to Eastport. Winds of moderate gale force occurred south of Nantucket, but to the northward winds were only fresh to strong.

On the 9th a disturbance of moderate intensity was central over the upper St. Lawrence Valley, and southwest storm warnings were displayed on the Atlantic coast from Delaware Breakwater to Eastport. A secondary storm developed off the southern Massachusetts coast on the morning of the 10th and warnings were changed to southeast from Nantucket to Eastport. Strong winds and gales occurred generally over the region indicated.

On the morning of the 13th there were indications of the development of a tropical disturbance over the southeastern Gulf of Mexico. This disturbance moved northwestward during the following 12 hours. It thence recurved rather sharply and moved slowly east-northeastward during the next two days, striking the northwest Florida coast near and east of Port St. Joe about 11 a. m. of the 15th. The highest winds at Port St. Joe have been estimated at 75 to 80 miles per hour from the northwest. At St. Andrews the winds at their highest were estimated at from 60 to 75 miles per hour and at Carrabelle from 40 to 50 miles with lowest barometer reading at the latter 29.10 inches at about 2:30 p. m. of the 15th. The lowest pressure reading at Apalachicola was 29.12 inches at 12:40 p. m. of the 15th, and the highest wind velocity was 68 miles per hour from the southeast.

In commenting on this disturbance the official in charge at Pensacola, Fla., writes as follows:

No report of damage at sea has been received with the exception of the three-masted schooner which was blown ashore near Carrabelle, and the blowing ashore of two fishing boats near Port St. Joe. The harbor damages were relatively small considering the force and duration of the storm, which is probably explained by the timely warnings which were evidently heeded, as is indicated by the St. Andrews storm warning display man, who states that all boats in the bay were placed in safe harbors upon receipt of the warnings.

From the time of the inception of this storm full information was disseminated by every available means to coast interests and to vessels at sea. While the storm did not attain hurricane intensity, winds of gale force occurred along its immediate path, and some damage to property between Carrabelle and St. Andrews is reported. The disturbance passed east-northeast across northern Florida and was central on the evening of the 16th on the South Carolina coast. It then continued its northeastward course and by the evening of the 18th was over the steamship routes south of Newfoundland. Strong winds and gales were general along the Atlantic seaboard, warnings of which were issued well in advance.

Pressure was low over the northwestern Caribbean from the 23d to the 27th, but vessel reports indicated no cyclonic circulation. On the 28th information was broadcast by radio announcing the presence of an incipient disturbance over the southeastern Gulf. Radio reports on the morning of the 29th showed a disturbance of slight but apprently increasing intensity moving northward, and storm warnings were hoisted on the east Gulf coast. Information was disseminated that the disturbance would move northeastward and cause dangerous gales along its path. The disturbance advanced rapidly north and northeastward and crossed the northwest Florida coast near Cedar Keys during the late afternoon of the 29th. During the afternoon of the 29th storm warnings were ordered for the south Atlantic coast from Jacksonville to Fort Monroe, Va., in anticipation of the northward movement of the tropical disturbance. By the following morning the storm was over the North Carolina coast with increased intensity. Storm warnings, which were displayed on the middle Atlantic coast in connection with a development over Virginia, were continued. Storm warnings were also ordered for the north Atlantic coast. The disturbance moved rapidly northward and easterly gales were experienced along the entire Atlantic seaboard.

Frost warnings were issued on the 10th for New York, Pennsylvania, New Jersey, West Virginia, and the eastern portions of Kentucky, Tennessee, and Ohio; and frosts occurred over portions of the States mentioned, but in other portions frost was prevented by cloudiness.

On the 23d, 24th, and 25th frost warnings were disseminated for portions of New England and the northern portion of the Middle Atlantic States, and frosts occurred substantially as indicated in the warnings. On the 30th frost warnings were issued for Tennessee and Kentucky and were verified. In addition, frosts occurred in the extreme north portion of the east Gulf States and in the southern Appalachian region.

During the early days of the month the special advices and bulletins furnished to the world fliers twice daily and at other times when required, materially assisted in the successful carrying out of their flying program.—*R. H. Weightman.*

CHICAGO FORECAST DISTRICT

Frost warnings.—September was cool over virtually the entire forecast district—decidedly so in the eastern portion, and frost warnings were required with greater frequency than usual. In fact ,warnings of this character were issued for some part of the district on no fewer than

23 days. The most important frosts were those of the closing 4 days of the month, when the formation was heavy or killing in all except extreme southeastern sections. Special attention was given to the warnings for Nebraska, Iowa, and Illinois, owing to the critical condition of the corn crop in respect to seed; and it is known that because of the warnings much seed corn was saved. Then, too, the warnings for the cranberry interests in Wisconsin served a useful purpose, as indicated in several letters that have come to hand. At the close of the month warnings were no longer being issued for most of the Northern Rocky Mountain region, the growing season there having terminated.

Storm warnings.—On the Great Lakes, particularly on the Lower Lakes, the month was more inclement than the average September. Storm warnings were issued on six days, and small-craft warnings on five other days.

No warnings of any character were issued until the 12th, although disturbances on the 2d and 5th caused gales of brief duration over central Lake Erie, and on the 8th–9th over part of the eastern Lake region, including extreme eastern Lake Superior. In some instances the winds referred to occurred in connection with thunderstorms.

On the 12th either southwest or northwest warnings were issued for practically all the Great Lakes, in connection with a disturbance over northern Lake Michigan, but the warnings were lowered in the evening, when the force of the storm appeared to have been spent. Generally speaking, the warnings were well verified.

The remainder of the second decade was mostly quiet, but on the morning of the 21st, with a disturbance of rapidly increasing energy central over southern Minnesota, warnings were issued for the Upper Lakes, and 12 hours later for the Lower Lakes. The center of the storm moved rapidly north-northeastward and later northeastward, and by the evening of the 22d had practically disappeared from the field of observation. The warnings issued in this connection were for the most part verified.

On the morning of the 26th a disturbance in the form of a trough and of some depth covered the Plains States, and at the same time a large high pressure area overlay the northeast, thus creating a marked gradient. Accordingly, warnings were issued for most of the Upper Lakes section. On the following morning, with the storm then decreasing in strength, small-craft warnings were advised for all the Great Lakes, except Lake Ontario.

Small-craft warnings were advised for the Lower Lakes on the 29th, when a disturbance of increasing energy covered the Middle and South Atlantic States, and indicated an almost due northward movement. As a result of afternoon special observations northeast storm warnings were issued for Lake Ontario, and at night these were extended westward on Lake Erie to the Cleveland district. The only verifying winds within the 36-hour period occurred at Cleveland, although 60 miles was reached at Buffalo, N. Y., on October 1.

The fire-weather forecasts for western Montana were discontinued for the season on the 20th, and those for the benefit of fruit interests in Door County, Wis., and southwestern Michigan, on the 30th.—*C. A. Donnel.*

NEW ORLEANS FORECAST DISTRICT

No storm occurred on the west Gulf coast during the month and no storm warnings were issued from New Orleans. Small-craft warnings were displayed on part of the Texas coast on the 12th, and all the Texas coast on the 28th.

Storm warnings were issued from the Central Office for New Orleans and Burrwood on the 13th and 14th, and for Burrwood on the 29th, but no storm verifying velocities occurred.

Frost warnings were issued on the 27th for the northwestern portion of the district, and on the 28th and 29th for the northern portion, and light frost occurred in scattered localities on the 28th, 29th, and 30th. No frost warnings were issued on the 20th, because at the rate the high-pressure area was traveling it would have been too far east by October 1 to give frost in this district; but it dropped southward with a slower eastward movement and light frost occurred in scattered localities in eastern Arkansas and northern Louisiana.—*I. M. Cline.*

DENVER FORECAST DISTRICT

Areas of low atmospheric pressure, followed by areas of high, crossed the district three times during the month, causing sharp falls in temperature, while at the beginning of the month another temperature and pressure transition was in progress. Warnings of frost were necessary and were issued for various appropriate portions of the district on the 1st, the 11th to 13th, the 18th to 22d, and the 25th to 29th, inclusive. Warnings of freezing or lower temperatures were included on the 20th for southwestern Colorado, northeastern Arizona, southern and extreme northwestern Utah, on the 21st for southwestern and exposed places in northern and eastern Colorado, northwestern New Mexico, northeastern Arizona, and exposed places in Utah; on the 26th for western Colorado, northwestern New Mexico, northeastern Arizona, and Utah; on the 27th for northwestern New Mexico and northeastern Arizona, and for exposed places in Colorado and Utah; on the 28th for southwestern Colorado and northwestern New Mexico, and on the 29th for exposed places in southwestern Colorado. On mornings subsequent to those on which the foregoing warnings were issued, temperatures were experienced far enough below freezing to kill green crops in the colder sections, while much damage was done to crops in the milder sections by temperatures of freezing and below.

As a result of the unusually dry summer a high fire hazard prevailed during a considerable portion of the month, consequently daily advice was published relative to the hazard in the forested districts, particularly for Colorado. The rains from the 9th to the 11th were especially beneficial in reducing the hazard for a time. Special warnings were issued on the 19th and 25th for southern Utah, Arizona, and New Mexico for increasing westerly winds which would add to the danger, due to the influence of low-pressure areas moving over the sections named without causing appreciable precipitation. The increase in the wind subsequent to the warning of the 25th was most pronounced, velocities of 46 miles an hour from a westerly direction being reported from the Weather Bureau stations at Modena, Utah, and Albuquerque, N. Mex.

Owing to the extremely low water in the lower Colorado River and the resultant heavy losses in the adjacent irrigation districts, numerous requests were answered relative to the probable rise that would be caused by the heavy rains which fell in the middle and upper drainage areas from the 9th to the 11th.—*Lawrence C. Fisher.*

SAN FRANCISCO FORECAST DISTRICT

The month was marked by a continuation of dry weather in California and by dry weather but with occasional local rains elsewhere until after the 18th, when more or less general rains occurred over the north Pacific States and Idaho. These rains were particularly beneficial in that they terminated a prolonged period of high forest-fire hazard in these regions. The only marked change to cooler weather generally over the district occurred during the period beginning on the 18th and ending on the 26th, when warnings of frost or of freezing temperature were required for Nevada and Idaho and the eastern parts of Washington and Oregon. It is worthy of note that this spell of unseasonably low temperatures followed an abnormal rise in pressure over the Bering Sea and the Aleutian Islands. The peak of high pressure occurred over the Bering Sea region on the 19th of September, followed by a rise to abnormally high pressure over the northern portion of this forecast district, which reached its maximum on the 26th and 27th. Southwest storm warnings were displayed on the 20th and continued on the 21st and 22d on the coast north of Cape Blanco. The first display was made well in advance of the occurrence of storm winds, which blew with gale force at and north of the mouth of the Columbia River. Again on the 29th, southwest storm warnings were displayed for the same area and were followed by winds of gale force during the 30th day of the month.

In the valleys of California there were no rains of appreciable amount to interfere with the drying of fruits, although on the 1st and on the 30th advisory information was sent to protect fruit, when the conditions were somewhat threatening.

The forest fire situation was acute during the entire month in California and during several periods in Washington, Oregon, and Idaho. Daily advices were issued to cover the forest-fire hazard resulting from the dangerous weather conditions.

The following letter from the California State Board of Forestry, dated September 18, 1924, addressed to the Weather Bureau office, Sacramento, has been received:

I wish to express my appreciation of the valuable service which you have rendered us this summer in notifying us of the approach of hot spells, low humidity and strong winds. On two occasions I have notified the State rangers that hazardous fire conditions were approaching after receiving information from your office to that effect. This information has enabled the rangers to prepare for these situations and probably has resulted in the saving of much valuable timber and watershed cover.

A continuance of the very efficient service which you have rendered the California State Board of Forestry will be much appreciated.

This communication was signed by State Forester M. B. Pratt.—*E. H. Bowie.*

RIVERS AND FLOODS

By H. C. FRANKENFIELD, Meteorologist

As will be seen in the table following, no floods of importance, except those beginning on the 30th and continuing into October in the Atlantic drainage area occurred in the principal rivers of the United States during September, 1924. That of the Illinois River, which was reported in the August number of this REVIEW, continued well into the month without additional damage of consequence. Along the lower Rio Grande some slight inconvenience and expense resulted, following the 25th, from moderate overflows and the necessity of repairs to and the patrolling of levees. The scattered mid-month rises in the Atlantic drainage area—specifically those in the Connecticut, Saluda (of South Carolina), and Broad (of Georgia) Rivers—were without serious damage. The more general floods that continued into October in the Atlantic area, which were of considerably greater extent and consequence, will be discussed in the October number of this REVIEW. Sufficient data are not now available.

Lock No. 8, Tennessee, on the Cumberland River was opened for service on September 15, 1924. This lock is 17.8 miles above Lock 7, and 124 miles above Nashville, Tenn. The normal pool stage maintained between Locks 7 and 8 is 6.0 feet, and the same above Lock 8 to Granville, Tenn., a distance of 16 miles. From Lock 8 to Lock 21, a distance of 173 miles, there are no locks and dams. The following item has been received from Mr. Roscoe Nunn.

The locks on the Cumberland River are now completed from Eddyville, Ky., up to Lock 8, and all-the-year navigation is possible in this part of the river, or from Eddyville, Ky., to Granville, Tenn., a distance of 290 miles. Below Eddyville, however, a 6-foot stage will not be available in the low-water season until a lock on the Ohio River, just below the mouth of the Cumberland, is completed. Work on this lock has just been started and it is expected that it will not be finished until 1929. The dam at this lock when in operation will back up the water to Lock F, Eddyville, making a 6-foot stage. Eddyville is 43 miles above the mouth of the Cumberland.

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
ATLANTIC DRAINAGE	*Feet*			*Feet*	
Connecticut: White River Junction, Vt.	15	11	14	15.9	13
Lehigh: Mauch Chunk, Pa	12	30	(1)		
Schuylkill: Reading, Pa	10	30	(1)		
Susquehanna: Binghamton, N. Y	14	30	(1)		
Chenango: Sherburne, N. Y	8	30	(1)		
James: Columbia, Va	18	30	(1)		
Roanoke: Weldon, N. C	30	30	(1)		
Tar: Rocky Mount, N. C	9	30	(1)		
Fishing Creek: Enfield, N. C	15	30	(1)		
Neuse:					
Neuse, N. C	15	30	(1)		
Smithfield, N. C	14	30	(1)		
Cape Fear:					
Fayetteville, N. C	35	30	(1)		
Elizabethtown, N. C	22	30	(1)		
Haw: Moncure, N. C	22	30	(1)		
Waccamaw: Conway, S. C	7	28	(1)		
Black: Kingstree, S. C	12	29	(1)		
Santee:					
Rimini, S. C	12	17	(1)	15.3	27
Ferguson, S. C	12	18	(1)		
Catawba: Catawba, S. C	12	30	(1)		
Congaree: Columbia, S. C	15	30	(1)		
Broad: Blairs, S. C	15	29	(1)		
Saluda:					
Pelzer, S. C	7	21	22	10.0	22
		30	(1)		
Chappells, S. C	14	16	16	14.1	16
		24	24	14.0	24
		30	(1)		
Broad: Carlton, Ga	11	26	26	11.6	26
Oconee:					
Milledgeville, Ga	22	26	(1)	31.5	26
Dublin, Ga	22	29	(1)		
Ocmulgee: Macon, Ga	18	30	(1)		
MISSISSIPPI DRAINAGE					
Shenango: Sharon, Pa	9	30	(1)		
Holston (North Fork): Mendota, Va	8	30	(1)		
Illinois:					
Peru, Ill	14	(2)	9	19.8	Aug. 11
Henry, Ill	7	(2)	25	13.7	Aug. 23, 24.
Peoria, Ill	16	(2)	10	21.0	Aug. 24
Havana, Ill	14	(2)	11	19.0	Aug. 25
Beardstown, Ill	12	(2)	21	19.1	Aug. 28, 29.
Pearl, Ill	12	(2)	10	15.7	Aug. 30
WEST GULF DRAINAGE					
Rio Grande:					
Rio Grande City, Tex	15	25	25	15.0	25
San Benito, Tex	21	18	29	24.2	27

[1] Continued at end of month. [2] Continued from last month.

MEAN LAKE LEVELS DURING SEPTEMBER, 1924

By UNITED STATES LAKE SURVEY

[Detroit, Mich., October 3, 1924]

The following data are reported in the "Notice to Mariners" of the above date:

Data	Lakes [1]			
	Superior	Michigan and Huron	Erie	Ontario
Mean level during September, 1924:	*Feet*	*Feet*	*Feet*	*Feet*
Above mean sea level at New York	601.89	579.51	571.95	245.65
Above or below—				
Mean stage of August, 1924	+0.24	−0.11	−0.21	−0.39
Mean stage of September, 1923	−0.15	−0.13	+0.44	+0.62
Average stage for September, last 10 years	−0.79	−1.10	−0.42	−0.37
Highest recorded September stage	−2.19	−3.92	−1.99	−1.96
Lowest recorded September stage	+0.40	−0.13	+0.67	+1.65
Average relation of the September level to—				
August level		−0.2	−0.2	−0.4
October level		+0.25	+0.3	+0.4

[1] Lake St. Clair's level: In September, 1924, 574.65 feet.

CORRECTION

REVIEW, March, 1924:

Page 181, 2d column, under head "Mississippi Drainage, Confluence, Pa.," flood stage of 19.0 feet should be "20.4 feet."

EFFECT OF WEATHER ON CROPS AND FARMING OPERATIONS, SEPTEMBER, 1924

By J. B. KINCER, Meteorologist

General summary.—Following the warm weather that prevailed in Central and Northern States east of the Rocky Mountains during the last two weeks in August, there was a reaction to cooler at the beginning of September, and the subnormal temperatures persisting in those sections throughout the month retarded the maturity of late crops. No material frost damage resulted, however, until the closing day of the month when heavy to killing frost overspread the Northwestern States, including the upper Mississippi Valley. It was much too wet for agricultural interests throughout the Atlantic States, where damaging drought had prevailed during the preceding month, but at the same time the abundant moisture was favorable for some truck and minor crops.

In most of Texas, the long drought which had prevailed practically throughout the summer in the west Gulf area was temporarily relieved, greatly improving soil conditions and benefiting late drops. In the central Gulf section, however, most vegetation suffered throughout the month, and it was too dry for the preparation of ground for fall seeding. It continued dry also in all sections west of the Rocky Mountains, except in the western portions of Washington and Oregon where rainfall during the month was somewhat above normal. Fall work made good progress in all sections, except where it was too wet in the Southeast.

Small grains.—In the Spring Wheat Belt rather frequent rains caused considerable interruption to threshing, but elsewhere late threshing made good progress with generally favorable weather. In nearly all parts of the principal producing area the soil was in good condition for preparation for wheat seeding, and at the end of the month sowing had become general in the Ohio Valley States and was about half done in Kansas. More rain was needed for this crop, however, in parts of the Great Plains, especially in Nebraska. The early seeded wheat in the western portion of the belt was coming up generally to a good stand.

Corn.—While light to moderate frost had checked the growth of corn in the northwestern portion of the belt, no material damage resulted to this crop until the heavy to killing frost in that section at the close of the month. The damaging frost was quite general in Wisconsin, Minnesota, and Iowa, and much harm was done in those States. There was some damage in Nebraska, but in the Ohio Valley States the crop largely escaped, while in Missouri and Kansas it had mostly matured before the frost came. In the Middle Atlantic area much of the corn crop was still green at the close of the month.

Cotton.—In the northern portion of the belt it was rather too cool for the development of late cotton, but in the western portion, especially in northern Texas and in Oklahoma, rainfall was beneficial to late plants. From the Mississippi Valley westward conditions, on the whole, were fairly favorable for this crop, but in the more eastern portions of the belt, especially in the Carolinas and Georgia, the frequent and heavy rainfall was decidedly unfavorable. Cotton deteriorated considerably in these States, the opening of bolls was checked, picking was retarded, and there was considerable complaint of seed sprouting, bolls rotting, and of lowering of the grade. In the central and western portions of the belt, conditions were more favorable for picking and ginning, and this work made good progress.

Miscellaneous.—In the Southeastern States, where rainfall was not too heavy, fall truck and minor crops were benefited by the increased moisture, and in much of Texas also the rainfall was helpful to them. In the central Gulf area rain was generally needed for all minor crops. In the Northern States the harvest of a satisfactory potato crop progressed well under favorable conditions. Sugar beets continued good to excellent in most sections where grown, but in the extreme lower Mississippi Valley sugar cane was very unfavorably affected by the prevailing drought. East of the Mississippi River pastures were mostly good for the season, except that they were poor and short in some sections of the Gulf States. The range remained good in the northern Great Plains and northern Rocky Mountain region, but in parts of the Southwest the prospects for winter range were poor, while feed was scarce in the Great Basin and in California.

CLIMATOLOGICAL TABLES[1]

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, September, 1924

Section	Temperature								Precipitation					
	Section average	Departure from the normal	Monthly extremes						Section average	Departure from the normal	Greatest monthly		Least monthly	
			Station	Highest	Date	Station	Lowest	Date			Station	Amount	Station	Amount
	° F.	° F.		° F.			° F.		In.	In.		In.		In.
Alabama	72.9	−2.6	2 stations	99	†1	Valley Head	30	30	3.31	−0.12	Alaga	9.98	Citronelle	0.60
Alaska														
Arizona	74.2	+1.4	2 stations	114	†2	Snowflake	22	22	0.80	−0.30	Spring Valley Ranger Station.	3.83	7 stations	0.00
Arkansas	69.7	−4.2	3 stations	103	†7	Dutton	29	30	3.99	+0.66	Brinkley	11.10	Junction	0.86
California	68.2	+1.1	Greenland Ranch	120	3	Sierraville	21	24	0.08	−0.47	Crescent City	1.87	128 stations	0.00
Colorado	56.5	−1.7	Lamar	103	5	Fraser	5	19	1.22	−0.12	Sedgwick	4.42	3 stations	0.00
Florida	78.8	−0.3	McDonald	102	12	Garniers	43	30	8.31	+1.97	Apalachicola	27.73	Sand Key	2.97
Georgia	71.7	−3.3	Statesboro	100	2	Blue Ridge	40	†8	10.67	+7.00	Quitman	23.97	Resaca	2.61
Hawaii	74.6	+0.1	Mahukona	92	3	2 stations	52	†7	3.83	−2.39	Pu Kukui (upper)	26.00	4 stations	0.00
Idaho	57.6	+0.6	Weiser	107	4	Rice	5	27	0.60	−0.40	Wallace	1.74	3 stations	T.
Illinois	61.9	−5.1	Fairfield	95	1	3 stations	30	30	3.13	−0.38	Shawneetown	7.03	Aledo	1.62
Indiana	62.1	−4.6	2 stations	96	†1	do	33	†6	3.70	+0.70	Kokomo	6.20	Greencastle	1.30
Iowa	59.1	−5.2	Cedar Rapids	91	21	Cedar Rapids	25	30	3.13	−0.53	Logan	5.68	Inwood	1.01
Kansas	65.6	−3.9	Cawker City	107	6	Burr Oak	24	29	2.65	−0.33	Independence	8.77	Mentor	0.06
Kentucky	65.3	−5.0	Earlington	97	1	2 stations	35	†6	4.44	+1.63	Middlesboro	8.94	Paducah	1.44
Louisiana	76.9	−0.6	Plain Dealing	104	11	Robeline	36	30	1.63	−2.37	New Orleans No. 2	4.87	3 stations	0.00
Maryland-Delaware	63.2	−3.9	Hancock, Md	101	1	3 stations	30	†7	6.02	+2.82	Laurel, Md	8.07	Cumberland, Md	3.83
Michigan	55.8	−3.9	Monroe	97	1	Sidnaw	18	30	2.80	−0.20	Bergland	4.71	Eagle Harbor	1.05
Minnesota	55.0	−3.4	Beardsley	92	3	2 stations	23	29	3.59	+0.81	Reeds	6.93	Pipestone	1.48
Mississippi	74.0	−2.1	2 stations	102	†1	Pontotoc	37	30	1.92	−1.35	Cleveland	4.98	Woodville	0.13
Missouri	64.0	−5.0	Caruthersville	96	8	Louisiana	29	30	3.77	+0.04	Fredericktown	8.92	Maryville	1.55
Montana	55.4	−0.3	Anaconda	97	4	Wheaton	10	26	0.87	−0.49	Norris	3.36	Poplar	0.01
Nebraska	60.3	−3.5	Newport	100	3	Ewing	23	29	2.24	+0.10	Tekamah	5.86	Auburn	0.38
Nevada	62.6	+0.4	Logandale	109	3	Quinn River Ranch	11	26	0.20	−0.24	McGill	1.04	7 stations	0.00
New England	58.0	−2.0	Waterbury, Conn	99	1	Pittsburg, N. H	22	26	5.45	+1.80	Bloomfield, Vt	10.48	Eastport, Me	2.45
New Jersey	62.2	−3.4	Moorestown	99	1	Charlotteburg	29	26	5.42	+1.83	Layton	8.44	Sandy Hook	2.48
New Mexico	64.3	−0.1	Carlsbad	102	7	2 stations	14	†26	0.60	−0.91	Porter	3.41	13 stations	0.00
New York	57.7	−3.2	Flushing	97	1	do	24	25	6.35	+2.85	Salisbury	9.87	Medford	2.59
North Carolina	66.5	−3.2	2 stations	100	1	Mount Mitchell	25	30	10.66	+6.78	Southport	21.10	Marshall	3.82
North Dakota	55.0	−1.4	Linton	98	3	Dunn Center	20	26	2.31	+0.67	Jamestown	5.12	New England	T.
Ohio	60.8	−4.8	2 stations	96	1	Canfield	31	24	4.80	+1.99	Warren	9.71	Cincinnati (Federal Building).	1.71
Oklahoma	70.9	−2.9	Hennessey	105	6	3 stations	33	28	2.97	−0.36	Vinita	6.81	Frederick	0.40
Oregon	59.6	+0.7	Kingman	103	4	Lapine	9	18	1.21	−0.11	Headworks	4.58	2 stations	T.
Pennsylvania	59.8	−3.9	Huntingdon	99	1	West Bingham	26	24	6.44	+3.16	Gordon	11.72	Philadelphia Navy Yard.	3.46
Porto Rico	78.4	−0.8	Mayaguez	99	†11	2 stations	59	†7	7.19	−0.97	Toro Negro	15.95	Vieques	2.27
South Carolina	70.5	−3.7	Winthrop College	100	1	Walhalla	41	10	12.74	+8.69	Wedgefield	17.32	Edgefield	6.87
South Dakota	59.0	−2.2	Belvidere	102	3	Meadow	25	28	1.53	−0.16	Academy	3.60	Sorum	0.10
Tennessee	67.2	−4.0	Sevierville	98	1	Crossville	33	6	4.59	+1.63	Clinton	11.71	Paris	2.34
Texas	75.6	−1.5	McKinney	107	8	Romero	32	28	2.89	+0.07	Trinidad	10.90	Seminole	0.00
Utah	59.8	−0.4	Hanksville	104	4	Woodruff	12	27	0.73	−0.41	Great Basin Experiment Station.	2.12	Delle	0.01
Virginia	64.0	−4.1	Danville	100	1	Burkes Garden	27	6	6.82	+3.36	Rocky Mount	10.41	Radford	3.03
Washington	59.4	+0.8	Omak	102	4	Snyder's ranch	23	20	1.68	+0.07	Silverton	7.85	Attalia	T.
West Virginia	60.7	−4.8	2 stations	100	1	Cheat Bridge	26	7	5.96	+3.14	Williamson	8.97	Burlington	2.80
Wisconsin	55.2	−4.5	do	88	21	Long Lake	17	30	3.22	−0.34	Wisconsin Rapids	6.36	Milwaukee	1.35
Wyoming	54.5	−0.9	3 stations	96	4	2 stations	10	†26	1.38	+0.13	Jackson	6.53	Hampshire (near)	0.00

[1] For description of tables and charts, see REVIEW, January, 1924, pp. 56–57.
† Other dates also.

TABLE 1.—*Climatological data for Weather Bureau stations, September, 1924*

Districts and stations	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dewpoint	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F		°F	°F.		°F	°F.	°F.	°F.	%	In.	In.		Miles								0-10	In.	In.
New England							**59.0**	**-1.9**										**82**	**4.70**	**+1.5**										**5.4**		
Eastport	76	67	85	30.00	30.08	+.05	54.5	-1.3	67	13	61	40	26	48	20	51	49	85	2.48	-0.5	11	6,336	s.	40	e.	10	8	8	14	6.3	0.0	0.0
Greenville, Me.	1,070	6		28.93	30.10		53.5		83	1	64	28	26	43	42				7.39		11		se.				12	5	13		0.0	0.0
Portland, Me	103	82	117	29.98	30.10	+.05	57.7	-1.9	84	1	65	39	25	50	27	54	51	81	4.09	+0.9	12	6,524	sw.	44	se.	30	12	7	11	5.1	0.0	0.0
Concord	288	70	79	29.78	30.09	+.03	58.0	-1.3	93	1	69	32	25	47	38				6.04	+2.8	13	3,052	se.	20	w.	14	10	8	12	5.5	0.0	0.0
Burlington	404	11	48	29.62	30.06	.00	57.3	-3.0	86	1	66	31	25	48	35				4.75	+1.4	11	7,211	s.	44	s.	9	11	3	16	6.0	0.0	0.0
Northfield	876	12	60	29.14	30.10	+.04	54.0	-2.1	86	1	66	27	25	42	40	50	49	91	6.27	+3.5	11	4,960	s.	38	ne.	1	11	6	13	6.1	0.0	0.0
Boston	125	115	188	29.96	30.09	+.02	62.2	-1.0	90	1	70	44	25	54	27	57	54	78	6.96	+3.8	11	6,220	w.	40	s.	30	10	10	10	5.4	0.0	0.0
Nantucket	12	14	90	30.08	30.09	+.01	60.8	-2.0	80	1	67	46	26	55	20	57	55	86	2.89	+0.2	9	11,041	ne.	57	n.	17	10	9	11	4.8	0.0	0.0
Block Island	26	11	46	30.06	30.09	+.01	61.2	-2.2	82	1	66	51	24	57	17	57	55	82	3.51	+0.5	7	11,251	se.	54	se.	30	10	12	8	4.4	0.0	0.0
Providence	160	215	251	29.92	30.09	+.02	61.0	-2.2	90	1	70	41	27	52	27	56	52	76	6.71	+3.5	9	7,464	s.	66	se.	30	12	11	7	4.6	0.0	0.0
Hartford	159	122	140	29.92	30.09	+.02	60.6	-1.1	91	1	71	39	27	50	32				4.63	+1.1	9		sw.				11	9	10	5.4	0.0	0.0
New Haven	106	74	153	29.98	30.09	+.02	61.0	-2.5	88	1	70	41	27	52	25	56	53	78	3.32	-0.5	11	6,654	ne.	48	s.	30	10	10	10	5.6	0.0	0.0
Middle Atlantic States							**63.1**	**-3.7**										**79**	**6.06**	**+2.7**										**6.2**		
Albany	97	102	115	29.97	30.08	+.01	60.1	-3.0	86	1	69	40	26	51	31	54	51	78	6.40	+3.2	9	5,040	s.	34	s.	29	10	10	10	5.6	0.0	0.0
Binghamton	871	10	84	29.12	30.06	-.01	58.4	-2.9	84	1	68	36	25	49	36				6.86	+4.1	10	3,816	w.	22	s.	8	6	6	18	7.1	0.0	0.0
New York	314	414	454	29.76	30.09	+.01	63.0	-3.8	92	1	70	46	11	56	30	57	53	75	3.16	-0.4	9	12,046	nw.	65	s.	30	7	7	16	6.6	0.0	0.0
Harrisburg	374	94	104	29.70	30.10	+.02	61.7	-4.1	93	1	70	41	25	53	27	56	52	73	6.52	+3.7	12	4,614	se.	26	se.	29	6	7	17	6.6	0.0	0.0
Philadelphia	114	123	190	29.97	30.10	+.02	65.0	-3.0	95	1	73	48	11	57	28	58	54	72	5.08	+1.7	9	6,446	e.	30	s.	30	7	6	17	6.7	0.0	0.0
Reading	325	81	98	29.74	30.09		62.0		94	1	71	42	25	53	28	56	53	79	6.33	+2.7	8	4,456	se.	24	se.	29	9	12	9	5.4	0.0	0.0
Scranton	805	111	119	29.23	30.09	+.02	59.0	-3.9	88	1	69	37	24	49	33	56	54	88	7.35	+4.5	10	4,344	n.	37	w.	2	8	7	15	6.4	0.0	0.0
Atlantic City	52	37	172	30.03	30.09	+.02	64.0	-2.8	91	1	70	47	24	58	23	60	57	79	3.50	+0.4	14	14,057	e.	82	se.	30	13	7	10	5.2	0.0	0.0
Cape May	18	13	49	30.10	30.12	+.05	65.2	-3.8	95	1	72	46	24	59	24	60	58	82	6.14	+3.1	13	6,252	se.	42	se.	30	10	5	15	6.2	0.0	0.0
Sandy Hook	22	10	55	30.06	30.08		63.6		92	1	69	48	11	58	28	58	55	77	2.47		10	11,288	s.	51	s.	30	8	10	12	5.6	0.0	0.0
Trenton	190	159	183	29.89	30.09		63.1		95	1	72	43	11	54	30	58	56	82	5.94	+2.4	10	7,757	ne.	39	sw.	30	8	8	14	6.2	0.0	0.0
Baltimore	123	100	113	29.95	30.08	.00	65.4	-3.1	94	1	73	45	11	58	29	59	55	73	5.75	+1.9	11	4,593	e.	27	se.	30	8	6	16	6.5	0.0	0.0
Washington	112	62	85	29.96	30.08	.00	64.3	-3.8	94	1	73	39	11	55	30	58	55	77	7.86	+4.3	11	4,553	nw.	48	nw.	2	8	7	15	6.4	0.0	0.0
Cape Henry	18	8	54	30.04	30.06		69.0		92	2	74	54	30	64	21	64	62	82	5.07	+1.0	13	11,727	ne.	53	ne.	17	7	9	14	6.5	0.0	0.0
Lynchburg	681	153	188	29.34	30.08	.00	64.0	-5.0	97	1	73	44	11	55	35	58	54	77	4.69	+1.1	13	5,217	ne.	34	s.	29	9	9	12	5.9	0.0	0.0
Norfolk	91	170	205	29.98	30.08	+.02	68.8	-2.8	93	1	75	54	30	62	22	63	60	80	6.59	+2.5	12	9,586	ne.	65	w.	30	7	9	14	6.5	0.0	0.0
Richmond	144	11	52	29.94	30.08	+.01	65.8	-4.7	96	1	74	46	11	57	32	60	56	78	9.58	+6.2	14	5,634	ne.	38	nw.	2	9	5	16	6.5	0.0	0.0
Wytheville	2,304	49	55	27.72	30.08	+.01	58.8	-4.8	87	1	68	36	6	50	34	54	52	84	6.27	+3.0	16	3,368	e.	24	w.	8	10	6	14	6.0	0.0	0.0
South Atlantic States							**70.6**	**-2.7**										**81**	**11.48**	**+6.8**										**6.2**		
Asheville	2,255	70	84	27.75	30.07	.00	62.2	-2.8	88	1	70	42	30	54	32	56	54	81	4.23	+1.3	12	5,751	se.	29	nw.	8	7	10	13	6.4	0.0	0.0
Charlotte	779	55	62	29.22	30.05	-.02	67.6	-3.9	97	1	76	46	30	60	31	61	58	78	10.84	+7.6	16	3,523	ne.	21	n.	1	8	9	13	6.3	0.0	0.0
Hatteras	11	11	50	30.03	30.04	-.02	71.8	-2.7	85	1	77	60	11	67	19	67	65	79	9.35	+4.0	13	10,823	ne.	52	s.	30	10	7	13	6.0	0.0	0.0
Manteo	12	5	42				68.6		94	1		46	7		28				13.27		10		ne.				8	9	13		0.0	0.0
Raleigh	376	103	110	29.67	30.06	-.01	67.4	-3.7	94	1	75	46	30	60	28	62	59	81	10.12	+6.8	19	5,858	ne.	31	nw.	2	10	7	13	6.4	0.0	0.0
Wilmington	78	81	91	29.96	30.04	-.01	70.9	-2.2	90	1	78	55	30	64	23	66	64	83	16.93	+11.7	14	5,432	e.	40	sw.	30	10	7	13	6.2	0.0	0.0
Charleston	48	11	92	29.96	30.01	-.03	74.6	-2.0	90	1	80	61	30	69	23	70	68	83	11.85	+6.4	14	8,268	ne.	44	ne.	16	7	11	12	6.4	0.0	0.0
Columbia, S. C	351	41	57	29.66	30.04	-.01	71.0	-3.5	93	1	79	50	30	63	27	65	62	83	11.48	+8.0	20	4,784	ne.	23	ne.	27	9	7	14	6.3	0.0	0.0
Due West	711	10	55	29.30	30.06		68.2		94	1	76	45	30	60	29				10.00		17	6,131	ne.	27	ne.	27	6	9	15	6.5	0.0	0.0
Greenville, S. C	1,039	113	122	28.96	30.04		67.4	-3.2	93	1	75	45	30	60	27	61	57	77	8.55		16	5,682	ne.	33	w.	2	9	8	13	5.9	0.0	0.0
Augusta	180	62	77	29.82	30.01	-.04	72.0	-3.3	93	1	80	53	30	64	27	66	64	82	8.22	+4.5	17	3,853	ne.	29	nw.	9	8	7	15	6.4	0.0	0.0
Savannah	65	150	194	29.93	30.00	-.03	74.4	-1.8	92	2	81	57	30	68	23	69	67	85	22.88	+17.3	17	7,616	ne.	44	nw.	30	9	8	13	5.9	0.0	0.0
Jacksonville	43	209	245	29.92	29.97	-.03	77.2	-1.1	91	9	83	58	30	71	17	71	69	82	8.88	+0.8	17	8,033	se.	69	s.	29	9	10	11	5.9	0.0	0.0
Florida Peninsula							**81.6**	**+0.4**										**77**	**6.76**	**-0.9**										**6.0**		
Key West	22	10	64	29.89	29.91	-.03	83.0	+0.8	92	4	88	73	26	78	17	76	74	77	5.10	-1.7	15	6,798	se.	36	se.	12	5	16	9	5.8	0.0	0.0
Miami	25	71	79	29.91	29.94		80.8	-0.7	89	4	86	71	4	76	18	75	73	77	7.41	-1.3	19	5,533	e.	33	se.	12	5	14	11	6.6	0.0	0.0
Sand Key	23	39	72	29.89	29.92	-.02	81.7		88	3	85	74	12	79	11	76	73	73	2.97		15	9,567	se.	43	e.	12	7	14	9	5.6	0.0	0.0
Tampa	35	79	87	29.90	29.93	-.04	81.0	+1.1	93	8	88	65	30	74	20	73	71	82	7.76	+0.4	12	4,747	e.	25	e.	26	9	10	11	6.1	0.0	0.0
East Gulf States							**73.4**	**-2.2**										**77**	**5.67**	**+1.8**										**5.1**		
Atlanta	1,174	190	216	28.81	30.04	-.01	68.2	-4.2	91	1	75	46	30	61	22	63	60	81	6.01	+2.5	17	7,373	e.	42	nw.	29	7	5	18	6.9	0.0	0.0
Macon	370	78	87	29.62	30.01	-.02	71.0	-3.8	90	1	79	49	30	63	27	65	63	83	12.30	+8.9	16	4,373	ne.	24	n.	22	8	7	15	6.6	0.0	0.0
Thomasville	273	49	58	29.67	29.96	-.05	75.6	-1.2	93	8	84	51	30	67	25	68	66	80	18.83	+14.6	12	3,456	ne.	27	ne.	15	6	9	15	6.6	0.0	0.0
Apalachicola	36	42	49	29.89	29.93		76.2		89	2	81	55	30	71	15	72	70	83	27.73		16	7,384	ne.	67	se.	15	14	5	11	5.0	0.0	0.0
Pensacola	56	149	185	29.90	29.96	-.03	75.8	-2.2	89	5	82	49	30	70	20	70	67	78	4.90	-0.3	8	9,371	e.	40	n.	29	9	12	9	5.3	0.0	0.0
Anniston	741	9	57	29.26	30.04	+.01	70.1	-1.2	90	8	79	41	30	61	31				6.05	+2.5	13	3,584	n.	19	n.	30	11	9	10	5.3	0.0	0.0
Birmingham	700	11	48	29.28	30.03	.00	72.1	-2.7	94	13	82	44	30	62	31	63	59	72	2.50	-1.0	9	4,919	n.	37	nw.	8	10	11	9	5.1	0.0	0.0
Mobile	57	125	161	29.91	29.97	-.03	76.3	-1.6	92	5	84	49	30	68	23	69	66	77	1.89	-3.1	6	7,445	n.	38	n.	29	11	14	5	4.3	0.0	0.0
Montgomery	223	100	112	29.76	30.00	-.02	73.5	-2.8	92	1	82	50	30	65	29	66	63	76	5.33	+2.4	11	4,827	ne.	28	n.	8	9	11	10	5.7	0.0	0.0
Corinth	469	6					70.8		94	21	82	42	30	60	38				3.20		8		n.				10	14	6		0.0	0.0
Meridian	375	85	93	29.60	29.99	-.03	72.4	-2.1	93	8	82	45	30	62	36	64	60	71	1.49	-2.0	4	4,194	e.	36	nw.	8	15	8	7	4.4	0.0	0.0
Vicksburg	247	65	73	29.74	30.02	.00	73.5	-2.8	96	20	84	45	30	63	30	64	60	72	0.51	-2.8	8	4,688	n.	25	n.	29	17	9	4	3.2	0.0	0.0
New Orleans	53	76	84	29.90	29.95	-.03	79.4	+0.2	92	8	87	56	30	72	20	70	67	73	2.59	-2.2	6	5,148	ne.	27	n.	29	18	9	3	3.3	0.0	0.0
West Gulf States							**75.5**	**-1.5**										**71**	**2.70**	**-0.8**										**3.4**		
Shreveport	249	77	93	29.73	30.00	.00	75.0	-1.9	99	8	86	48	30	64	34	64	59	67	1.06	-2.2	6	4,489	ne.	26	w.	21	20	7	3	2.8	0.0	0.0
Bentonville	1,303	11	44				65.2	-3.7	91	7	76	37	30	54	31				6.77		8	2,937	n.	20	s.	19	19	5	6		0.0	0.0
Fort Smith	457	79	94	29.53	30.01	.00	70.9	-3.1	97	7	81	44	30	60	35	62	57	69	3.54	+0.4	7	5,055	e.	33	n.	1	17	7	6	3.7	0.0	0.0
Little Rock	357	136	144	29.65	30.02	-.01	69.8	-4.3	93	1	79	46	30	60	30	61	57	71	5.44	+2.2	9	5,525	n.	48	n.	1	16	6	8	4.1	0.0	0.0
Brownsville	57	53	61	29.83	29.90		80.2	-0.4	94	1	88	56	30	73	25	73	71	81	7.29		9	4,903	se.	25	n.	29	15	10	5	4.3	0.0	0.0
Corpus Christi	20	11	73	29.92	29.94	-.01	80.4	+0.7	92	2	87	59	30	74	20	74	72	80	1.60	-2.4	8	8,289	e.	34	se.	19	17	8	5	3.4	0.0	0.0
Dallas	512	109	117	29.46	30.00		74.8		100	8	85	47	30	65	32				3.04		7	5,442	s.	32	se.	19	18	8	4	3.0	0.0	0.0
Fort Worth	670	106	114	29.27	29.98	-.01	74.3	-2.6	100	8	85	49	30	64	30	64	58	64	3.78	+0.8	6	6,324	se.	38	se.	19	17	8	5	3.2	0.0	0.0
Galveston	54	106	114	29.91	29.97	-.01	80.2	+0.1	90	9	86	61	30	75	16	72	68	72	0.04	-5.4	2	7,129	n.	28	n.	28	23	7	0	2.0	0.0	0.0
Groesbeck	461	11	56	29.50	29.97		75.1		97	6	86	47	30	64	34				3.64		6	6,353	ne.	29	sw.	19	16	7	7	3.6	0.0	0.0
Houston	138	111	121	29.82	29.96		79.0	0.0	96	6	89	52	30	69	28				1.25		5	4,816	n.	23	se.	12	13	12	5	4.1	0.0	0.0
Palestine	510	64	72	29.46	29.99	.00	75.0	-2.0	97	8	85	49	30	65	30	65	60	67	4.49	+1.3	4	5,081	ne.	30	n.	21	15	10	5	3.4	0.0	0.0
Port Arthur	34	58	66	29.91	29.95		78.6		94	9	87	50	30	70	28	70	66	74	0.47		5	6,252	n.	29	n.	29	21	6	3	2.6	0.0	0.0
San Antonio	693	119	132	29.24	29.96	.00	78.4	-0.6	96	21	89	52	30	68	30	66	61	65	2.52	-0.4	7	5,324	e.	27	nw.	28	14	12	4	3.9	0.0	0.0
Taylor	583	55	63	29.39	30.00	+.03	77.1	+0.3	98	9	88	49	30	66	31				1.87	-1.2	7	5,556	n.	30	s.	19	14	9	7	3.7	0.0	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, September, 1924*—Continued

Districts and stations	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature: Departure from normal	Temperature: Maximum	Temperature: Date	Temperature: Mean maximum	Temperature: Minimum	Temperature: Date	Temperature: Mean minimum	Temperature: Greatest daily range	Mean wet thermometer	Mean temperature of the dewpoint	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F		°F	°F.		°F	°F.	°F.	°F.	%	In.	In.		Miles								0-10	In.	In.
Ohio Valley and Tennessee							**64.1**	**−4.6**										**74**	**4.36**	**+1.6**										**5.8**		
Chattanooga	762	189	213	29.23	30.04	−.02	68.3	−3.9	89	8	77	44	30	60	32	60	55	69	4.20	+1.0	14	5,301	n.	43	nw.	8	11	7	12	5.4	0.0	0.0
Knoxville	996	102	111	29.00	30.05	−.01	66.3	−4.3	92	1	76	44	30	57	31	60	57	77	6.80	+4.0	13	4,318	ne.	30	w.	8	6	10	14	6.8	0.0	0.0
Memphis	399	76	97	29.61	30.03	.00	69.2	−4.4	90	20	78	42	30	61	26	61	57	72	5.19	+2.1	8	4,864	n.	50	sw.	19	15	4	11	4.2	0.0	0.0
Nashville	546	168	191	29.49	30.07	+.01	67.9	−3.9	90	21	77	42	30	59	34	61	56	73	2.64	−1.0	12	7,039	nw.	36	s.	19	13	8	9	4.7	0.0	0.0
Lexington	989	193	230	29.01	30.07	.00	63.7	−4.8	88	1	72	40	30	55	30	......	......	......	3.89	+1.5	11	9,081	se.	48	w.	21	10	9	11	5.4	0.0	0.0
Louisville	525	188	234	29.50	30.08	+.02	65.3	−5.2	91	1	74	44	10	56	28	57	53	69	4.83	+2.2	12	7,828	n.	34	n.	1	11	11	8	5.1	0.0	0.0
Evansville	431	139	175	29.61	30.07	+.01	66.2	−4.5	90	21	76	40	30	56	31	58	53	68	5.89	+3.2	10	7,739	ne.	52	w.	21	8	18	4	5.2	0.0	0.0
Indianapolis	822	194	230	29.19	30.08	+.02	61.7	−5.2	86	1	71	40	30	53	29	55	51	73	2.80	−0.2	15	8,435	n.	37	w.	8	7	14	9	5.5	0.0	0.0
Royal Center	736	11	55	29.28	30.07	......	58.0		88	21	69	33	10	47	36				2.90		11	6,420	n.	29	n.	9	5	13	12	6.2	0.0	0.0
Terre Haute	575	96	129	29.45	30.06	......	62.4		90	21	72	40	30	53	32	56	53	77	3.70	......	10	6,621	n.	34	sw.	21	6	15	9	5.6	0.0	0.0
Cincinnati	628	11	51	29.40	30.07	.00	62.5	−4.6	89	1	72	41	30	53	28	......	53	73	2.07	−0.2	15	4,812	ne.	22	s.	20	11	8	11	5.6	0.0	0.0
Columbus	824	179	222	29.21	30.08	+.01	61.4	−5.1	87	1	70	41	10	53	27	55	51	75	3.77	+1.2	12	7,928	nw.	36	nw.	9	8	9	13	6.3	0.0	0.0
Dayton	899	137	173	29.11	30.06		62.0	−4.6	89	1	71	42	30	53	29	55	50	71	2.92	+0.4	13	6,388	n.	32	sw.	8	8	11	11	5.6	0.0	0.0
Elkins	1,947	59	67	28.06	30.10	+.02	58.7	−4.3	88	1	69	36	6	48	36	53	51	86	5.39	+2.5	16	3,305	w.	25	nw.	29	5	6	19	7.5	0.0	0.0
Parkersburg	638	77	84	29.44	30.09	+.01	62.8	−4.5	91	1	72	42	6	54	28	56	53	77	5.28	+2.6	13	3,424	n.	24	nw.	9	7	9	14	6.8	0.0	0.0
Pittsburgh	842	353	410	29.18	30.08	.00	61.4	−5.0	88	1	69	42	11	53	26	55	51	75	5.39	+2.9	16	7,537	se.	50	nw.	5	5	10	15	6.9	0.0	0.0
Lower Lake Region							**59.0**	**−4.0**										**74**	**5.66**	**+2.8**										**6.1**		
Buffalo	767	247	280	29.24	30.07	+.01	58.3	−4.1	77	27	66	38	30	51	26	53	49	77	6.48	+3.3	12	10,708	s.	60	w.	22	8	7	15	6.2	0.0	0.0
Canton	448	10	61	29.55	30.02		55.9	−3.4	80	1	66	31	24	46	36	......	......	......	5.61	+2.8	12	5,604	w.	33	sw.	6	10	8	12	5.4	0.0	0.0
Oswego	335	76	91	29.68	30.05	−0.01	58.0	−3.2	80	12	65	39	25	51	3	53	49	74	5.55	+2.7	11	7,291	se	30	ne.	2	7	10	13	6.0	0.0	0.0
Rochester	523	86	102	29.50	30.07	+.01	58.8	−3.6	83	1	68	40	30	50	30	53	49	74	5.71	+3.4	13	5,257	s.	30	nw.	6	9	5	16	6.2	0.0	0.0
Syracuse	597	97	113	29.43	30.08	+.01	58.4	−3.2	83	1	66	39	24	50	28	......	......	......	6.76	+3.9	10	6.874	s.	35	s.	22	7	7	16	6.5	0.0	0.0
Erie	714	130	166	29.29	30.06	.00	60.2	−3.4	82	12	67	43	30	53	24	54	50	74	7.19	+3.7	15	11,090	nw.	41	n.	2	8	11	11	5.8	0.0	0.0
Cleveland	762	190	201	29.25	30.07	+.01	60.4	−3.5	81	21	67	44	30	54	26	54	50	73	6.08	+2.9	16	10,189	s.	55	n.	2	5	5	20	7.1	0.0	0.0
Sandusky	629	62	70	29.38	30.07	+.01	60.8	−4.5	83	21	68	45	30	54	26				5.44	+2.8	15	6,402	s.	32	n.	9	4	13	13	6.6	0.0	0.0
Toledo	628	208	243	29.40	30.09	+.03	59.8	−4.6	82	1	67	41	10	52	22	53	49	73	5.19	+2.8	11	9,119	nw.	49	sw.	21	12	3	15	5.6	0.0	0.0
Fort Wayne	856	113	124	29.16	30.09	......	59.6	−5.9	86	21	68	39	10	51	30	54	50	78	2.76	......	10	5,616	nw.	24	w.	22	7	8	15	6.3	0.0	0.0
Detroit	730	218	258	29.30	30.09	+.03	59.4	−4.1	83	1	67	41	10	52	22	52	48	72	2.61	+0.1	12	7,402	nw.	38	sw.	12	11	6	13	5.7	0.0	0.0
Upper Lake Region							**55.4**	**−4.3**										**80**	**2.64**	**−0.6**										**5.7**		
Alpena	609	13	92	29.41	30.08	+.05	53.1	−4.5	74	1	62	35	11	45	27	50	47	82	2.20	−1.3	11	8,573	se.	56	s.	21	6	13	11	6.2	0.0	0.0
Escanaba	612	54	60	29.40	30.06	+.05	52.8	−4.3	68	3	61	33	30	45	25	49	46	80	2.42	−1.2	8	6,691	s.	35	sw.	21	13	8	9	4.8	'.	0.0
Grand Haven	632	54	89	29.38	30.07	+.03	56.3	−4.6	86	21	64	35	30	48	33	52	49	80	2.25	−0.9	11	6,732	n.	46	w.	22	8	11	11	5.6	0.0	0.0
Grand Rapids	707	70	87	29.31	30.08	+.03	58.2	−3.6	89	21	67	37	30	50	34	52	48	75	3.48	+0.4	10	3,736	nw.	28	nw.	21	5	10	15	6.6	0.0	0.0
Houghton	668	62	99	29.31	30.03	+.03	53.6	−3.3	78	26	62	34	30	46	28	......	......	......	2.29	−1.2	8	6,738	w.	55	nw.	22	12	7	11	5.3	'.	0.0
Lansing	878	11	62	29.13	30.08	......	56.8	−4.6	85	21	67	35	30	46	31	51	49	84	2.58	0.0	11	3,355	n.	17	sw.	22	9	12	9	5.6	0.0	0.0
Ludington	637	60	66	29.37	30.07	......	54.9	......	82	21	62	35	30	48	29	51	49	83	1.33	......	11	6,499	n.	44	w.	22	11	9	10	4.9	0.0	0.0
Marquette	734	77	111	29.27	30.08	+.08	53.2	−4.3	75	26	61	34	30	45	25	49	47	82	2.42	−1.1	9	6,561	w.	38	sw.	21	10	7	13	5.8	0.0	0.0
Port Huron	638	70	120	29.37	30.06	00	57.2	−4.4	79	1	65	37	11	49	24	52	49	77	2.99	+0.3	12	8,084	nw.	32	w.	13	5	16	9	5.4	0.0	0.0
Saginaw	641	69	77	29.38	30.08	......	56.4	−5.4	83	21	65	37	11	47	28	51	48	79	3.15	0.0	11	5,461	sw.	35	sw.	22	5	10	15	6.8	0.0	0.0
Sault Sainte Marie	614	11	52	29.37	30.07	+.05	52.6	−2.9	71	3	60	35	30	45	32	49	46	84	1.66	−1.8	8	6,013	nw.	40	nw.	22	11	9	10	5.7	0.0	0.0
Chicago	823	140	310	29.19	30.08	+.04	60.3	−6.0	90	21	66	40	30	54	39	54	50	71	3.14	+0.1	14	7,947	ne.	35	w.	21	11	8	11	5.4	0.0	0.0
Green Bay	617	109	144	29.38	30.04	+.02	55.8	−4.6	81	21	64	33	30	48	32	50	47	77	3.04	−0.1	10	6,894	se.	44	sw.	21	10	7	13	5.7	0.0	0.0
Milwaukee	681	125	139	29.33	30.06	+.03	57.2	−5.3	86	21	63	36	30	51	35	52	49	76	1.35	−1.6	9	6,975	n.	36	sw.	21	11	6	13	5.7	0.0	0.0
Duluth	1,133	11	47	28.82	30.04	+.06	52.7	−2.4	76	3	62	28	29	44	31	48	46	85	3.95	+0.4	8	7,200	ne.	64	nw.	21	11	7	12	5.4	0.0	0.0
North Dakota							**55.8**	**−1.3**										**70**	**2.46**	**+1.0**												
Moorhead	940	50	58	28.98	30.00	+.04	55.8	−2.4	83	3	66	37	28	46	37	50	46	76	3.17	+0.9	7	5,980	s.	28	se.	23	14	5	11	4.8	0.0	0.0
Bismarck	1,674	8	57	28.22	30.00	+.06	57.2	−.06	89	3	70	32	27	45	43	48	42	67	1.60	+0.4	9	6,519	nw.	36	s.	9	12	9	9	5.0	0.0	0.0
Devils Lake	1,478	11	44	28.40	29.98	+.04	54.3	−1.3	83	2	65	33	29	43	37	47	43	74	4.54	+3.2	9	6,182	se.	31	ne.	26	12	7	11	5.2	0.0	0.0
Ellendale	1,457	10	56	28.43	30.00	......	55.6	......	92	3	68	31	29	44	44	......	......	......	2.73	......	9	9,492	s.	38	s.	23	11	6	13	5.7	0.0	0.0
Grand Forks	835	12	89	......	......	......	53.9	......	82	2	66	32	5	42	42	......	......	......	3.19	......	8	......	nw.	46	se.	18	17	6	7	......	0.0	0.0
Williston	1,878	41	48	27.97	29.95	+.02	56.0	−0.6	89	2	69	26	27	43	45	47	40	63	0.52	−0.4	6	5,053	se.	31	se.	8	17	8	5	3.7	0.0	0.0
Upper Mississippi Valley							**61.0**	**−5.1**										**77**	**2.81**	**−0.5**										**5.1**		
Minneapolis	918	102	208	29.03	30.01	......	57.6	−3.8	78	3	66	36	30	49	31	......	......	......	3.43	−0.2	8	7,779	se.	54	nw.	21	10	7	13	5.9	0.0	0.0
St. Paul	837	236	261	29.12	30.03	+.04	56.7	−4.6	76	3	65	32	30	48	32	......	......	......	3.05	−0.4	9	8,461	se.	63	sw.	21	10	10	10	5.6	0.0	0.0
La Crosse	714	11	48	29.28	30.05	+.04	57.0	−5.2	84	21	67	31	30	47	35	......	......	......	3.58	−0.5	10	2,712	w.	34	s.	21	9	10	11	5.8	0.0	0.0
Madison	974	70	78	29.03	30.08	+.05	56.8	−5.6	82	21	65	36	30	49	34	51	48	78	2.87	−0.3	11	5,735	se.	31	sw.	21	8	7	15	6.1	0.0	0.0
Wausau	1,247	4	......	28.75	30.09	......	53.0	......	77	21	63	28	30	43	34	......	......	......	1.83	......	6	......	n.	......	......	......	15	5	10	4.4	0.0	0.0
Charles City	1,015	10	49	28.98	30.06	+.06	56.8	−4.9	83	21	67	30	30	47	36	51	48	80	4.00	+1.2	11	4,292	se.	32	sw.	21	11	10	9	4.9	0.0	0.0
Davenport	606	71	79	29.40	30.07	+.04	60.4	−5.2	84	21	70	36	30	51	33	54	50	76	2.23	−0.9	8	4,815	e.	35	w.	21	14	7	9	4.6	0.0	0.0
Des Moines	861	84	97	29.13	30.04	+.02	60.5	−5.1	81	7	71	33	30	50	30	54	50	76	3.47	+0.4	10	4,944	e.	33	sw.	21	11	8	11	5.2	0.0	0.0
Dubuque	700	81	96	29.30	30.05	+.02	58.2	−5.8	85	21	67	34	30	49	36	52	48	77	2.44	−1.2	11	4,170	se.	25	sw.	21	8	8	14	6.0	0.0	0.0
Keokuk	614	64	78	29.39	30.06	+.03	61.4	−6.1	84	20	72	36	30	51	33	56	52	77	1.70	−2.3	7	4,915	e.	36	w.	21	13	7	10	4.8	0.0	0.0
Cairo	358	87	93	29.67	30.04	−.01	66.4	−5.1	88	21	75	41	30	58	28	59	56	75	2.84	+0.4	8	6,003	n.	30	n.	29	12	11	7	4.6	0.0	0.0
Peoria	609	11	45	29.42	30.08	+.04	60.4	−3.9	88	21	71	38	30	50	40	54	52	81	3.74	+0.6	6	3,886	n.	25	sw.	21	16	7	7	4.0	0.0	0.0
Springfield, Ill	636	10	91	29.37	30.05	.00	62.2	−5.4	89	21	72	39	30	52	38	55	52	76	2.02	−1.4	9	5,505	n.	31	nw.	1	12	8	10	4.8	0.0	0.0
Hannibal	534	74	109	29.49	30.06	+.03	62.3	−5.4	87	20	73	33	30	52	35	......	......	......	2.02	−1.5	10	5,558	n.	30	sw.	21	16	5	9	4.5	0.0	0.0
St. Louis	568	265	303	29.45	30.05	+.01	65.0	−5.1	89	21	74	40	30	56	34	58	54	75	1.97	−0.9	6	8,209	s.	50	se.	19	12	9	9	4.8	0.0	0.0
Missouri Valley							**62.1**	**−3.9**										**70**	**3.12**	**+0.4**										**4.5**		
Columbia, Mo	784	11	84	29.22	30.05	+.02	62.7	−5.5	90	11	73	33	30	52	32	......	......	......	4.99	+2.1	10	4,844	se.	32	nw.	7	13	7	10	4.9	0.0	0.0
Kansas City	963	161	181	29.00	30.03	+.01	65.0	−3.9	90	11	74	42	30	56	37	57	53	71	4.68	+0.9	7	6,760	s.	38	w.	7	12	13	5	4.2	0.0	0.0
St. Joseph	967	11	49	28.98	30.02	......	63.4	......	91	7	75	35	30	52	38	56	52	75	5.78	......	10	5,371	se.	41	nw.	21	14	10	6	4.0	0.0	0.0
Springfield, Mo	1,324	98	104	28.65	30.05	+.02	63.8	−5.1	86	7	73	39	30	55	29	57	53	75	4.12	+0.4	12	6,838	se.	33	nw.	1	17	9	4	3.3	0.0	0.0
Iola	984	11	50	28.98	30.01	.00	65.7	−2.9	90	1	78	36	30	54	33	......	......	......	6.14	+2.8	8	4,104	se.	25	n.	1	14	12	4	3.8	0.0	0.0
Topeka	987	92	107	......	......	......	64.4	−4.3	90	11	75	38	30	54	36	......	......	......	4.15	+0.6	9	6,708	se.	37	sw.	11	13	12	5	3.9	0.0	0.0
Drexel	1,299	10	54	28.63	30.02	......	59.7	......	80	3	70	33	29	49	33	......	......	......	4.13	......	6	6,412	se.	36	nw.	21	13	6	11	5.0	0.0	0.0
Lincoln	1,189	11	84	28.76	30.01	+.02	62.8	−3.6	85	6	74	34	29	52	32	53	47	66	0.95	−1.7	8	6,911	se.	43	nw.	21	12	7	11	5.0	0.0	0.0
Omaha	1,105	115	122	28.85	30.03	+.03	62.2	−4.6	81	7	72	40	29	53	31	54	51	73	4.56	+1.5	5	5,331	se.	31	nw.	21	14	7	9	4.6	0.0	0.0
Valentine	2,598	47	54	27.29	30.00	+.04	59.0	−3.5	96	3	72	32	28	47	46	50	44	66	1.58	−0.2	9	7,212	s.	39	nw.	26	9	13	8	4.7	0.0	0.0
Sioux City	1,135	94	164	28.82	30.04	+.06	59.4	−4.0	80	3	70	35	29	49	32	52	48	72	1.71	−0.8	8	8,264	se.	48	w.	21	10	12	8	5.0	0.0	0.0
Huron	1,306	59	74	28.62	30.02	+.06	58.5	−2.8	87	3	70	31	29	47	34	51	46	70	1.45	−0.2	10	6,940	se.	32	s.	23	11	11	8	4.5	0.0	0.0
Pierre	1,572	70	75	28.32	29.97	+.02	61.9	−1.9	99	3	74	34	28	50	42	52	47	66	1.98	+0.9	9	6,793	se.	34	n.	26	10	9	11	5.1	0.0	0.0
Yankton	1,233	49	57	28.70	30.01	+.03	59.7	−4.3	85	3	70	29	29	49	33	......	......	......	1.09	−1.4	7	5,470	se.	33	nw.	21	10	13	7	5.1	0.0	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, September, 1924*—Continued

Districts and stations	Elevation of instruments: Barometer above sea level	Thermometer above ground	Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Departure from normal	Maximum	Date	Mean maximum	Minimum	Date	Mean minimum	Greatest daily range	Mean wet thermometer	Mean temperature of the dewpoint	Mean relative humidity	Precipitation: Total	Departure from normal	Days with 0.01, or more	Wind: Total movement	Prevailing direction	Maximum velocity: Miles per hour	Direction	Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F		°F	°F.		°F	°F.	°F.	°F.	%	In.	In.		Miles								0–10	In.	In.
Northern Slope							**56.3**	**−1.1**										**58**	**1.10**	**0.0**										**4.2**		
Billings	3,140	5					57.6		93	3	76	24	27	39	54				0.48		5		nw.				14	8	8		0.0	0.0
Havre	2,505	11	44	27.31	29.93	−.01	57.0	+0.6	92	4	73	27	27	40	48	47	38	60	0.64	−0.4	7	4,249	sw.	26	w.	23	12	13	5	3.8	0.0	0.0
Helena	4,110	87	112	25.80	29.95	−.02	57.3	+0.7	92	4	71	32	27	44	41	44	32	47	1.15	+0.1	8	6,097	sw.	40	sw.	17	12	10	8	4.3	T.	0.0
Kalispell	2,973	48	56	26.91	29.94	−.02	53.8	+0.3	85	2	68	30	27	40	44	44	35	56	0.90	−0.4	8	3,885	nw.	26	sw.	23	12	11	7	4.3	T.	0.0
Miles City	2,371	48	55	27.46	30.00	+.05	59.0	−2.2	90	2	73	31	27	45	47	48	39	57	0.15	−0.8	4	3,730	nw.	24	nw.	6	17	7	6	3.4	0.0	0.0
Rapid City	3,259	50	58	26.61	30.00	+.04	59.0	−1.4	95	3	72	34	27	46	45	47	37	52	0.91	−0.4	9	5,561	w.	36	sw.	18	16	7	7	4.2	T.	0.0
Cheyenne	6,088	84	101	24.06	29.98	+.02	54.6	−2.4	85	3	68	29	27	41	39	45	39	63	2.36	+1.4	10	7,553	w.	52	sw.	9	15	9	6	4.1	T.	0.0
Lander	5,372	60	68	24.69	29.99	+.03	55.4	−0.3	87	4	71	24	27	40	46	43	33	50	0.44	−0.6	3	3,533	sw.	36	sw.	5	15	9	6	4.2	1.4	0.0
Sheridan	3,790	10	47	26.12	30.00		54.8		88	2	72	27	27	38	51	44	37	63	1.03		10	2,982	nw.	26	nw.	9	14	10	6	4.0	T.	0.0
Yellowstone Park	6,200	11	48	23.94	30.02	+.05	49.8	−3.6	84	4	64	24	27	36	44	40	32	59	1.67	+0.7	10	4,928	s.	37	s.	23	13	9	8	4.5	2.3	0.0
North Platte	2,821	11	51	27.11	30.02	+.05	60.5	−1.6	95	3	73	32	29	48	42	52	48	73	1.66	+0.2	9	4,841	se.	25	se.	9	12	11	7	4.7	0.0	0.0
Middle Slope							**65.2**	**−2.8**										**59**	**1.52**	**−0.4**										**3.0**		
Denver	5,292	106	113	24.78	29.98	+.02	60.4	−2.5	91	3	73	34	27	48	38	48	38	51	1.44	+0.6	7	4,601	s.	29	ne.	26	18	8	4	3.2	T.	0.0
Pueblo	4,685	80	86	25.32	29.95	−.01	63.4	−1.2	95	5	81	30	27	46	55	48	37	48	0.10	−0.5	1	4,721	e.	40	nw.	26	22	7	1	2.5	0.0	0.0
Concordia	1,392	50	58	28.54	30.01	+.02	64.4	−3.9	99	6	77	34	29	52	40	54	48	64	0.80	−1.8	5	5,807	s.	35	nw.	21	15	8	7	4.1	0.0	0.0
Dodge City	2,509	11	51	27.44	30.01	+.03	66.0	−3.4	99	6	80	36	29	52	39	54	48	64	1.62	−0.2	6	7,501	se.	37	se.	25	21	6	3	2.2	0.0	0.0
Wichita	1,358	139	158	28.57	29.99	−.01	67.2	−3.4	96	6	79	40	29	56	37	57	51	64	2.51	−0.6	8	9,526	s.	55	s.	11	17	10	3	3.2	0.0	0.0
Broken Arrow	765	11	52	29.20	30.02		68.2		95	1	80	44	30	56	32				5.42		8	8,261	se.	46	se.	19	15	12	3	3.3	0.0	0.0
Muskogee	652	4					70.6		100	1	84	41	30	57	38				5.80		8		se.				18	7	5		0.0	0.0
Oklahoma City	1,214	10	47	28.74	30.00	+.01	70.1	−2.7	97	7	82	45	29	58	32	59	54	64	2.65	−0.1	6	6,954	s.	33	w.	26	19	7	4	2.5	0.0	0.0
Southern Slope							**71.9**	**−1.6**										**58**	**2.23**	**−0.2**										**3.2**		
Abilene	1,738	10	52	28.19	29.98	+.02	72.4	−2.9	96	8	84	43	30	61	37	61	55	66	4.05	+0.9	7	5,735	s.	30	s.	26	18	4	8	3.5	0.0	0.0
Amarillo	3,676	10	49	26.32	30.00	+.04	67.6	−1.7	94	4	82	42	28	53	41	56	50	64	1.13	−1.2	4	7,219	s.	30	s.	20	26	3	1	3.2	0.0	0.0
Del Rio	944	64	71	28.97	29.94	.00	77.5	−1.7	96	1	87	52	29	68	28				3.73	+1.2	9	5,692	se.	40	n.	2	13	8	9	4.4	0.0	0.0
Roswell	3,566	75	85	26.38	29.93	+.01	70.0	−0.3	96	7	85	39	30	55	47	54	41	44	T.	−1.8	0	5,616	s.	30	s.	20	26	4	0	1.5	0.0	0.0
Southern Plateau							**72.4**	**+1.8**										**39**	**0.18**	**−0.7**										**1.2**		
El Paso	3,762	110	133	26.19	29.87	−.01	74.6	+1.7	95	8	86	49	29	63	33	58	46	41	0.14	−1.3	2	7,677	e.	38	w.	18	26	4	0	1.3	0.0	0.0
Santa Fe	7,013	38	53	23.33	29.90	−.03	60.4	−0.5	84	3	75	33	27	46	36	46	33	44	0.62	−1.0	7	4,450	e.	33	sw.	18	24	5	1	1.9	0.0	0.0
Flagstaff	6,907	10	59	23.43	29.90	+.01	56.8	+1.3	82	1	73	28	22	41	47	44		52	2.77		7	5,121	w.	33	sw.	25	20	7	3		0.0	0.0
Phoenix	1,108	76	81	28.65	29.77	−.04	85.6	+2.9	107	13	101	58	27	70	45	66	54	40	0.12	−0.9	4	3,208	e.	19	n.	10	26	2	2	1.5	0.0	0.0
Yuma	141	9	54	29.60	29.74	−.04	86.7	+3.0	110	6	103	58	25	71	42	66	53	39	0.02	−0.1	1	3,324	sw.	33	se.	6	28	2	0	0.9	0.0	0.0
Independence	3,957	5	25	25.95	29.92	−.06	70.6	+2.	697	3	88	37	21	53	45	48	21	18	T.	−0.1	0	5,803	se.	42	w.	19	29	1	0	0.6	0.0	0.0
Middle Plateau							**62.0**	**+0.1**										**32**	**0.30**	**−0.4**										**2.4**		
Reno	4,532	74	81	25.47	29.92	−.03	61.8	+2.1	89	6	79	33	27	45	48	45	29	35	0.02	−0.3	1	4,808	w.	35	w.	23	23	6	1	1.6	0.0	0.0
Tonopah	6,090	12	20				63.6		85	1	74	32	20	53	27	46	26	28	0.28		1		se.								0.0	0.0
Winnemucca	4,344	18	56	25.63	29.98	+.05	58.5	−0.7	92	7	79	20	26	38	53	42	25	35	0.13	−0.2	1	4,489	ne.	32	s.	7	23	5	2	2.0	0.0	0.0
Modena	5,479	10	43	24.65	29.92	.00	60.6	+0.6	90	3	79	23	21	42	49	44	26	34	0.13	−1.0	1	6,949	sw.	52	sw.	7	21	8	1	2.0	0.0	0.0
Salt Lake City	4,360	163	203	25.63	29.95	.00	64.4	0.0	97	4	76	36	27	53	33	49	37	41	0.25	−0.6	3	5,274	s.	36	se.	9	16	8	6	3.6	T.	0.0
Grand Junction	4,602	60	68	25.41	29.96	+.01	64.5	−1.7	98	4	78	35	21	51	44	50	39	46	0.97	0.0	5	4,435	se.	28	nw.	20	20	6	4	2.8	0.0	0.0
Northern Plateau							**62.1**	**+1.4**										**44**	**0.58**	**−0.2**										**3.9**		
Baker	3,471	48	53	26.44	30.00	+.01	58.0	+2.0	93	4	73	27	26	42	47	45	33	46	0.17	−0.6	4	4,731	se.	30	s.	7	9	12	9	5.1	0.0	0.0
Boise	2,739	78	86	27.14	29.97	.00	63.8	+1.9	100	4	78	31	26	49	42	48	33	37	0.24	−0.2	5	3,552	se.	25	nw.	17	21	3	6	3.0	0.0	0.0
Lewiston	757	40	48	29.15	29.95	−.03	64.4	+1.6	100	7	80	38	27	49	46				0.49	−0.2	6	2,117	e.	20	nw.	5	15	4	11	4.4	0.0	0.0
Pocatello	4,477	60	68	25.49	29.96	.00	60.2	0.0	94	4	75	30	20	46	41	45	31	39	0.82	−0.1	6	5,760	se.	40	sw.	9	16	8	6	3.9	0.2	0.0
Spokane	1,929	101	110	27.92	29.95	−.03	60.7	+1.5	92	7	74	36	27	47	44	49	38	51	0.90	−0.1	7	3,771	sw.	36	s.	8	16	4	10	3.7	0.0	0.0
Walla Walla	991	57	65	28.88	29.94	−.06	65.2	+1.4	96	7	77	40	27	53	39	69	42	48	0.89	0.0	8	3,043	s.	22	w.	18	18	8	4	3.4	0.0	0.0
North Pacific Coast Region							**58.8**	**+0.5**										**73**	**2.97**	**+0.6**										**4.8**		
North Head	211	11	56	29.78	30.00	−.03	55.3	−1.2	85	12	60	47	26	51	31	53	51	88	3.28	+1.4	13	12,427	n.	70	s.	22	7	6	17	6.6	0.0	0.0
Port Angeles	29	8	53		29.99		54.6		81	12	64	38	26	46	35				2.67	+0.8	7	4,170	s.	31	w.	23	17	6	7		0.0	0.0
Seattle	125	215	250	29.87	30.00	−.01	59.5	+1.4	87	12	68	45	26	51	34	54	49	72	2.68	+0.9	9	6,057	s.	44	s.	21	11	8	11	5.0	0.0	0.0
Tacoma	194	172	201	29.78	29.99	−.03	58.9	+1.6	90	12	68	40	26	50	39				2.46	+0.4	8	5,902	s.	39	s.	21	8	10	12	6.4	0.0	0.0
Tatoosh Island	86	7	57	29.87	29.97	−.04	53.2	+0.2	70	12	57	45	19	49	20	52	51	94	6.47	+0.3	12	10,771	s.	67	s.	21	8	9	13	6.0	0.0	0.0
Yakima	1,071	5					62.2		94	4	80	28	27	44	49				0.50		4		w.				18	5	7	3.5		
Medford	1,425	4					64.2		97	1	83	32	26	45	59	50	41	55	0.92		6		nw.				14	4	12	3.2	0.0	0.0
Portland, Oreg.	153	68	106	29.82	29.98	−.05	63.4	+1.7	92	12	74	43	25	53	34	55	49	64	1.93	+0.1	8	4,207	nw.	22	nw.	3	13	8	9	4.7	0.0	0.0
Roseburg	510	9	57	29.46	30.01	−.01	62.4	−0.5	98	1	77	37	22	48	51	53	45	64	1.33	+0.3	9	2,414	n.	23	sw.	22	18	9	3	3.2	0.0	0.0
Middle Pacific Coast Region							**63.8**	**+0.5**										**60**	**0.08**	**−0.5**										**3.0**		
Eureka	62	73	89	29.95	30.02	+.01	54.9	−1.0	81	11	61	42	20	49	33	52	50	88	0.41	−0.7	8	3,855	n.	31	n.	18	9	7	14	6.0	0.0	0.0
Point Reyes	490	7	18	29.40	29.92		55.8	−0.3	80	11	61	46	28	50	27				T.		0	12,054	nw.	83	nw.	19	11	6	13	5.6	0.0	0.0
Red Bluff	332	50	56	29.53	29.87	−.06	73.6	+0.5	101	6	89	47	22	58	44	56	40	34	0.00	−0.8	0	4,415	se.	27	nw.	10	27	3	0	2.0	0.0	0.0
Sacramento	69	106	117	29.81	29.88	−.01	70.8	+1.5	102	6	86	48	17	56	42	56	43	45	T.	−0.4	0	5,744	s.	39	nw.	21	29	1	0	0.4	0.0	0.0
San Francisco	155	208	243	29.76	29.93	−.01	62.4	+1.5	88	11	70	51	24	54	30	55	50	75	T.	−0.3	0	6,282	w.	30	w.	24	25	3	2	2.2	0.0	0.0
San Jose	141	12	110	29.76	29.91		65.3	+0.6	95	11	80	43	21	50	43				T.	−0.3	0	4,030	nw.	27	sw.	7	26	4	0	2.0	0.0	0.0
South Pacific Coast Region							**69.0**	**+0.4**										**60**	**T.**	**−0.2**										**1.6**		
Fresno	327	89	98	29.51	29.86	−.01	75.2	+1.8	105	6	92	47	26	58	39	56	39	33	0.00	−0.3	0	5,029	nw.	26	nw.	7	29	1	0	0.4	0.0	0.0
Los Angeles	338	159	191	29.51	29.87	−.01	70.0	+1.0	102	29	81	53	11	58	31	58	52	64	T.	−0.1	0	3,344	sw.	14	w.	1	21	8	1	2.0	0.0	0.0
San Diego	87	62	70	29.77	29.86	−.03	66.4	−0.7	88	29	73	54	28	60	26	61	58	79	0.00	−0.1	0	4,706	nw.	21	nw.	16	24	6	0	2.5	0.0	0.0
San Luis Obispo	201	32	40	29.71	29.92	−.01	64.2	−0.3	99	28	78	44	30	50	47	53	47	66	0.00	−0.4	0	2,827	nw.	17	nw.	25	27	3	0	1.5	0.0	0.0
West Indies																																
San Juan, P. R.	82	9	54	29.85	29.93		80.2	−0.3	91	3	85	73	23	75	14				5.72	−1.1	14	6,661	e.	40	e.	12	5	19	6	5.9	0.0	0.0
Panama Canal																																
Balboa Heights	118	7	97	29.73	29.85	+.02	78.6	−1.2	87	1	84	70	23	73	14	75	74	91	12.55	+4.7	24	4,502	s.	27	s.	23	0	13	17	7.8	0.0	0.0
Colon	36	7	97	29.82	29.86	+.02	81.9	+1.7	92	16	89	72	20	75	18	76	75	90	9.00	−3.4	21	4,630	se.	29	s.	1	1	10	19	7.9	0.0	0.0
Alaska																																
Juneau	80	11	54	29.73	29.82		48.8		61	30	54	34	24	44	22	46	43	86	18.85		23	5,354	s	35	e.	22	2	0	28	9.2	0.0	0.0

TABLE II.—*Data furnished by the Canadian Meteorological Service, September, 1924*

Stations	Altitude above mean sea level, Jan. 1, 1919	Pressure			Temperature of the air						Precipitation		
		Station reduced to mean of 24 hours	Sea level reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. ÷2	Departure from normal	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure from normal	Total snowfall
	Feet	*In.*	*In.*	*In.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	*In.*	*In.*	*In.*
St. Johns, N. F	125												
Sydney, C. B. I	48	30.03	30.08	+.07	58.2	+1.7	68.0	48.5	80	38	3.42	+0.14	0.0
Halifax, N. S	88	29.99	30.09	+.05	58.1	+0.5	69.2	47.1	80	36	6.39	+2.68	0.0
Yarmouth, N. S	65	29.98	30.05	.00	55.5	−0.6	63.7	47.3	73	35	4.03	+0.58	0.0
Charlottetown, P. E. I	38	30.02	30.06	+.05	58.3	+1.0	64.7	51.9	72	44	0.78	−2.62	0.0
Chatham, N. B	28	29.96	29.90	−.01	55.5	+0.1	67.2	43.8	80	32	2.78	+0.07	0.0
Father Point, Que	20	29.98	30.00	+.02	46.8	−3.6	56.0	37.7	73	28	4.98	+1.85	0.0
Quebec, Que	296	29.72	30.04	+.03	55.4	+0.3	63.9	47.0	76	34	7.89	+4.22	0.0
Montreal, Que	187	29.82	30.02	−.02	56.5	−1.9	64.1	48.9	78	39	7.72	+4.42	0.0
Stonecliffe, Ont	489												
Ottawa, Ont	236	29.77	30.03	−.01	57.4	0.0	68.2	46.6	82	34	3.90	+1.21	0.0
Kingston, Ont	285	29.75	30.06	+.02	58.2	−1.8	65.6	50.8	74	40	5.46	+2.66	0.0
Toronto, Ont	379	29.65	30.05	−.01	57.0	−2.0	65.5	48.5	81	38	4.14	+0.89	0.0
Cochrane, Ont	930												
White River, Ont	1,244	28.69	30.01	+.03	49.3	−1.0	61.3	37.4	76	22	2.66	−0.11	0.0
Port Stanley, Ont	592												
Southampton, Ont	656	29.34			55.1	−2.4	63.7	46.5	76	35	2.91	−0.03	0.0
Parry Sound, Ont	688	29.35	30.05	+.02	54.5	−1.5	63.7	45.3	75	34	3.14	−0.53	0.0
Port Arthur, Ont	644	29.33	30.04	+.06	51.7	−0.5	60.0	43.5	75	28	3.79	+0.31	0.0
Winnipeg, Man	760												
Minnedosa, Man	1,690	28.15	29.96	+.02	51.8	+1.3	63.4	40.3	76	26	2.10	+0.74	0.0
Le Pas, Man	860				52.2		65.6	38.9	81	22	0.92		0.0
Qu'Appelle, Sask	2,115	27.68	29.91	−.01	53.6	+2.5	67.6	39.7	85	25	0.40	−0.93	0.0
Medicine Hat, Alb	2,144	27.58	29.82	−.10	58.3	+3.3	73.1	43.6	89	30	1.18	0.00	0.0
Moose Jaw, Sask	1,759				55.0		70.3	39.7	88	26	0.73		0.0
Swift Current, Sask	2,392	27.40	29.91	−.01	54.9	+1.8	70.6	39.3	87	22	0.65	−0.57	0.0
Calgary, Alb	3,428												
Banff, Alb	4,521	25.36	29.89	−.04	50.2	+4.4	64.1	36.3	82	25	0.99	−0.68	0.0
Edmonton, Alb	2,150												
Prince Albert, Sask	1,450	28.36	29.93	+.03	53.9	+5.5	67.3	40.5	82	30	1.63	+0.35	T.
Battleford, Sask	1,502	28.16	29.89	−.01	55.8	+4.0	70.8	40.8	86	28	1.76	+0.51	0.0
Kamloops, B. C	1,262												
Victoria, B. C	230	29.72	29.97	−.04	57.2	+2.4	65.0	49.5	82	43	2.26	+0.10	0.0
Barkerville, B. C	4,180												
Triangle Island, B. C	680												

LATE REPORTS, AUGUST, 1924

Barkerville, B. C	4,180	25.68	29.96	+.06	51.6	−4.7	61.8	41.5	72	31	5.01	+1.91	0.0
Kamloops, B. C	1,262	28.66	29.92	−.01	67.5	−1.1	79.6	55.5	90	43	0.89	−0.20	0.0
Calgary, Alb	3,428	26.40	29.91	.00	58.9	−0.5	73.6	44.2	92	34	4.46	+2.32	0.0

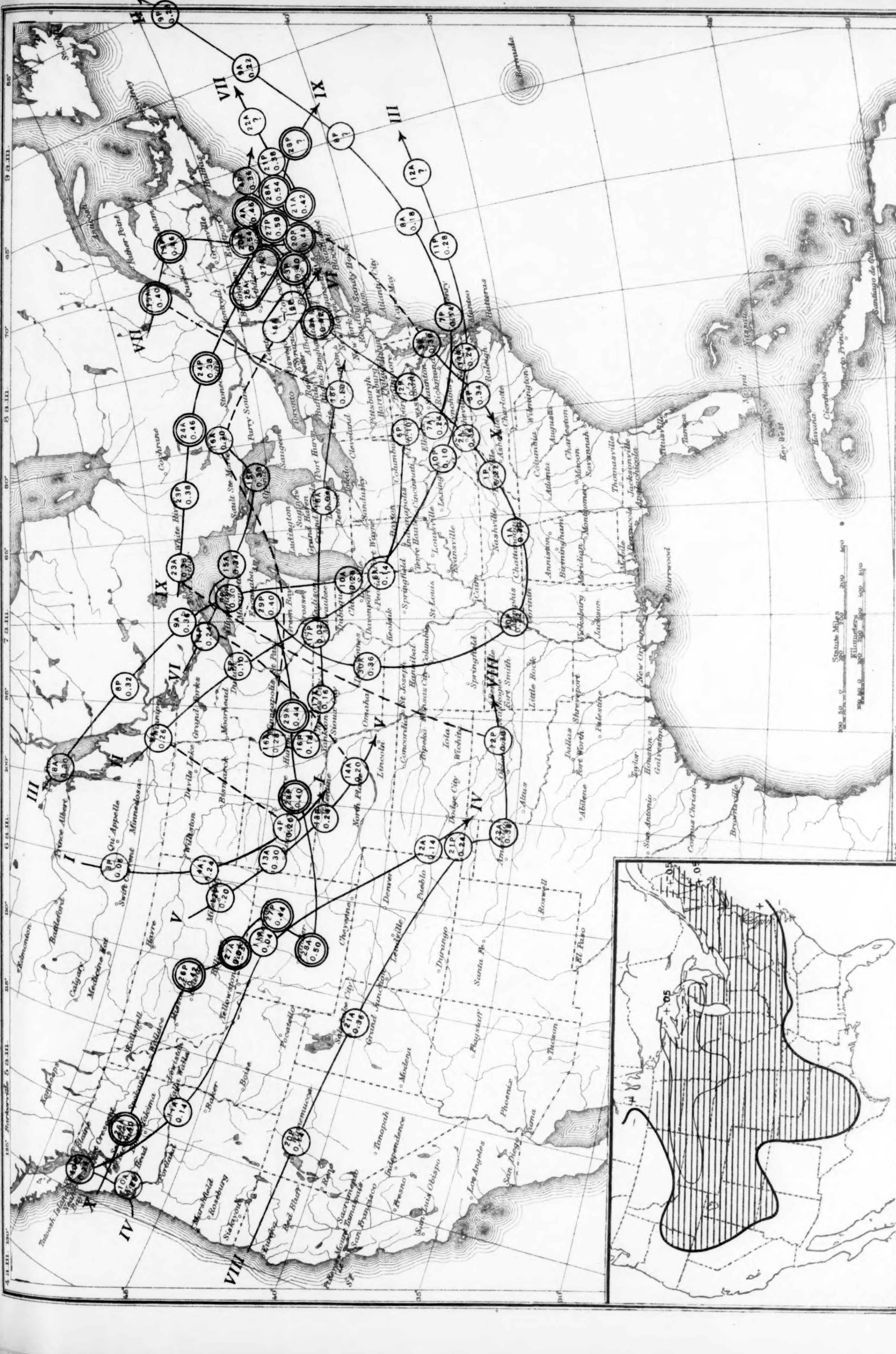
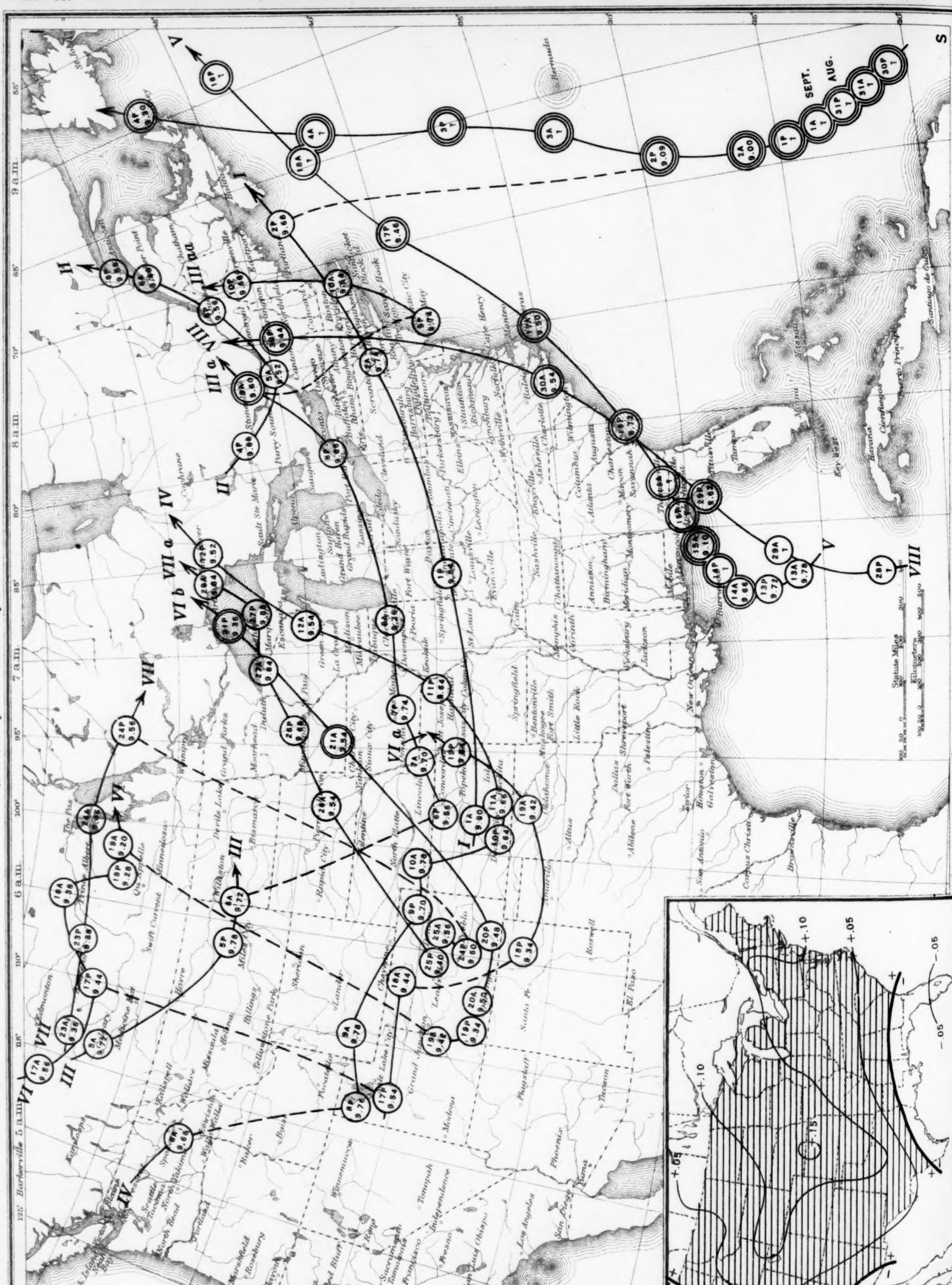

(Plotted by Wilfred F. Day.)

Chart II. Tracks of Centers of Cyclones, September, 1924. (Inset) Change in Mean Pressure from Preceding Month.

(Plotted by Wilfred P. Day.)



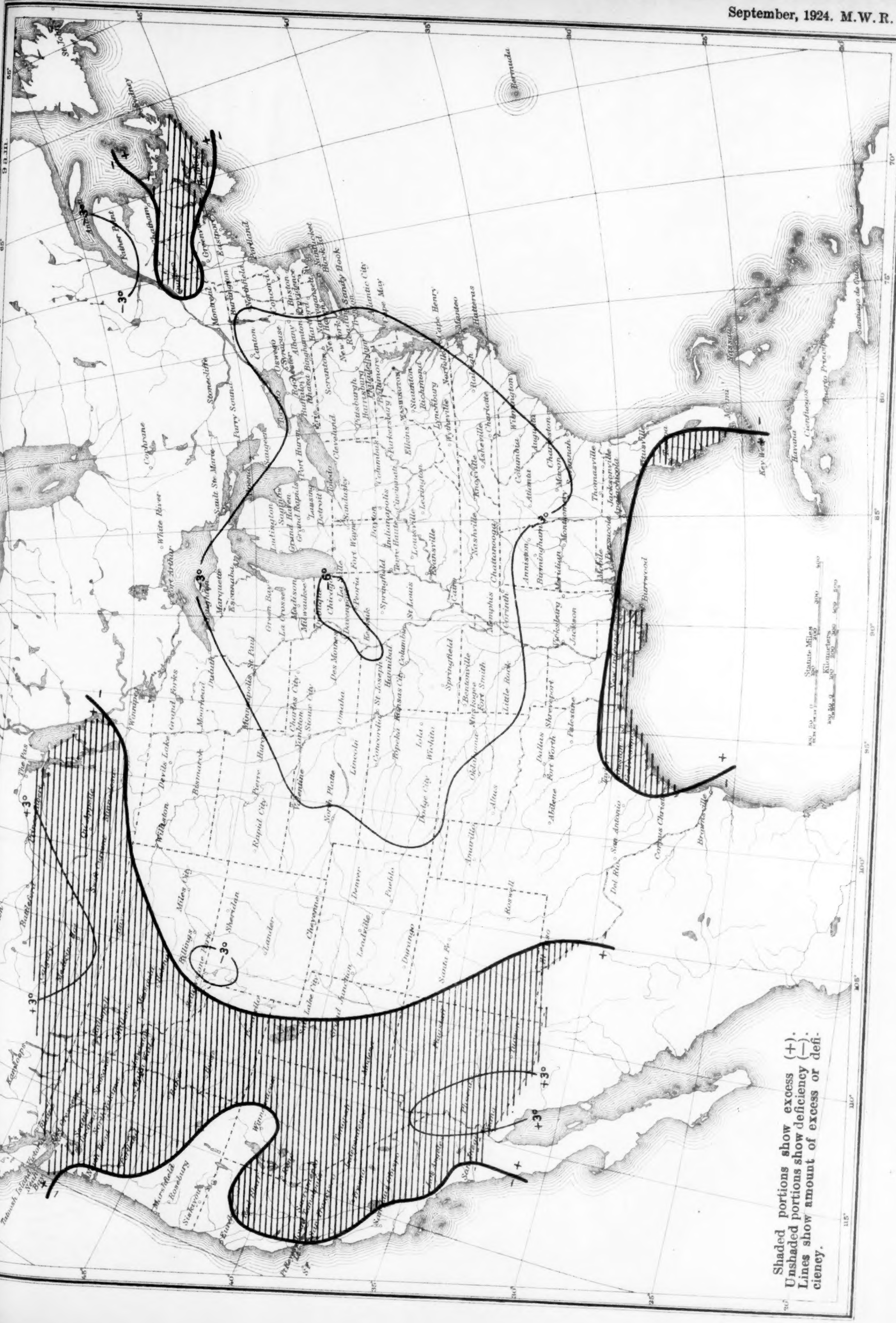
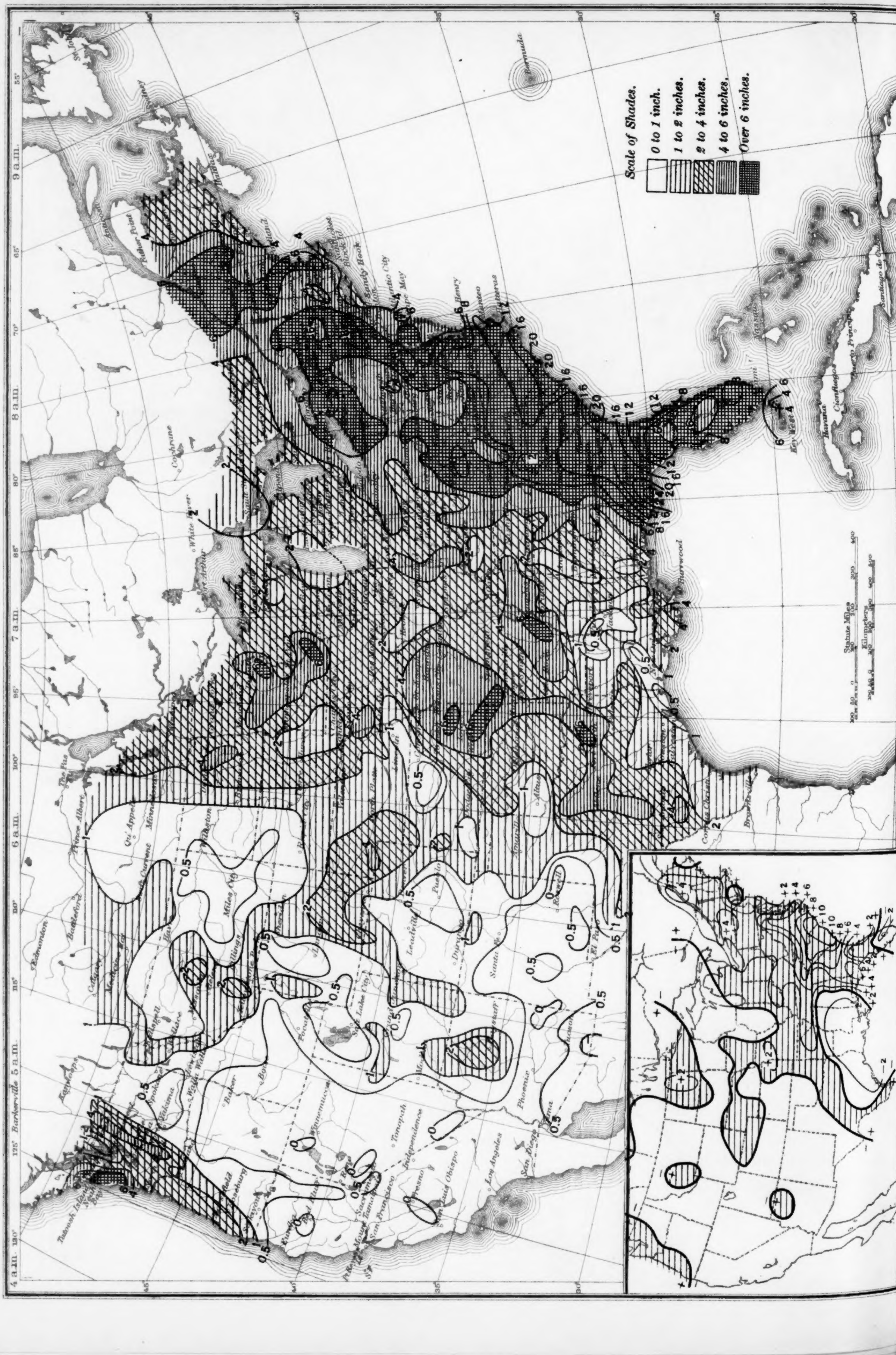

Shaded portions show excess (+).
Unshaded portions show deficiency (—).
Lines show amount of excess or deficiency.
+3°
−3°
6°

Chart IV. Total Precipitation, Inches, September, 1924. (Inset) Departure of Precipitation from Normal.



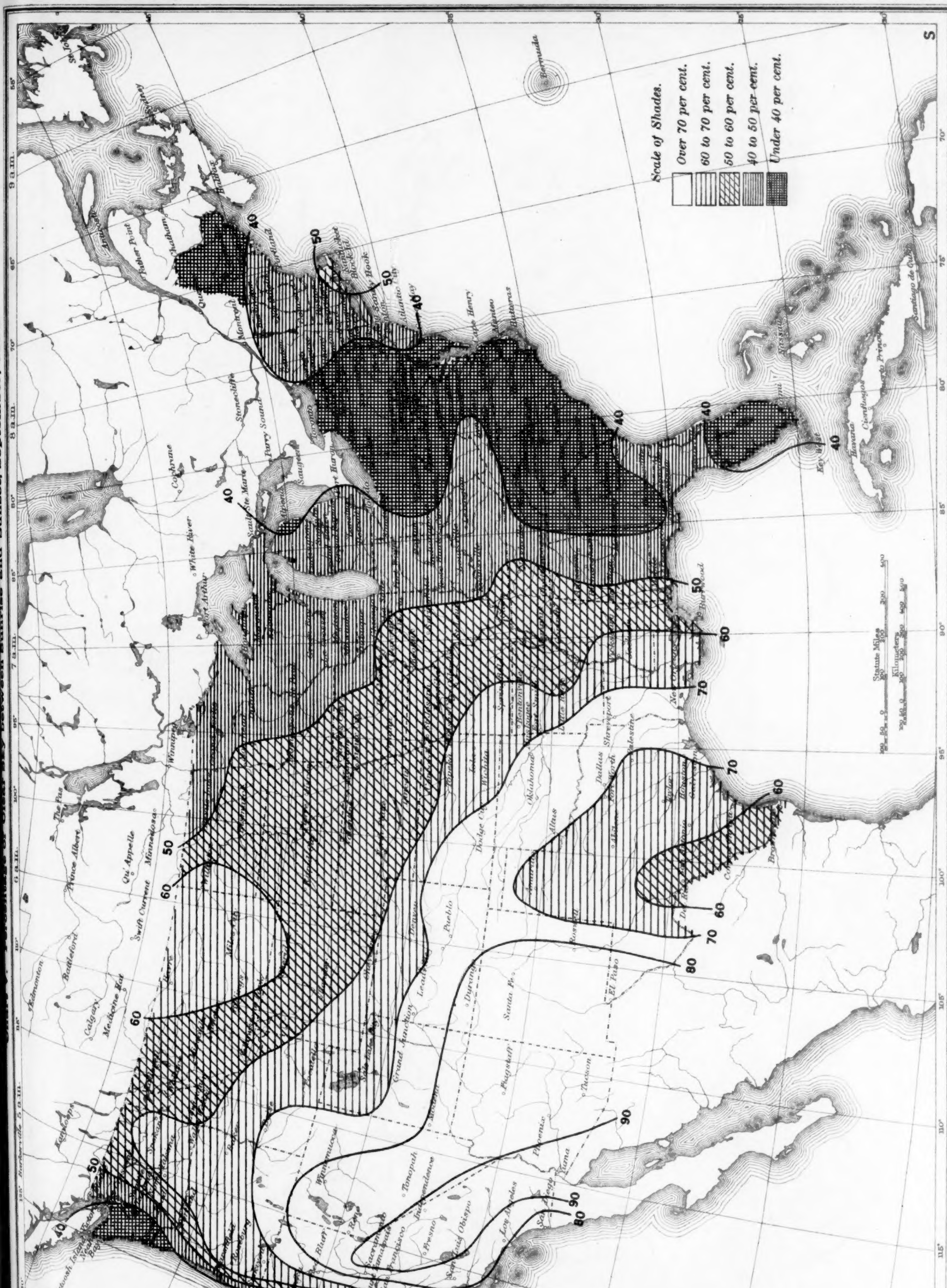
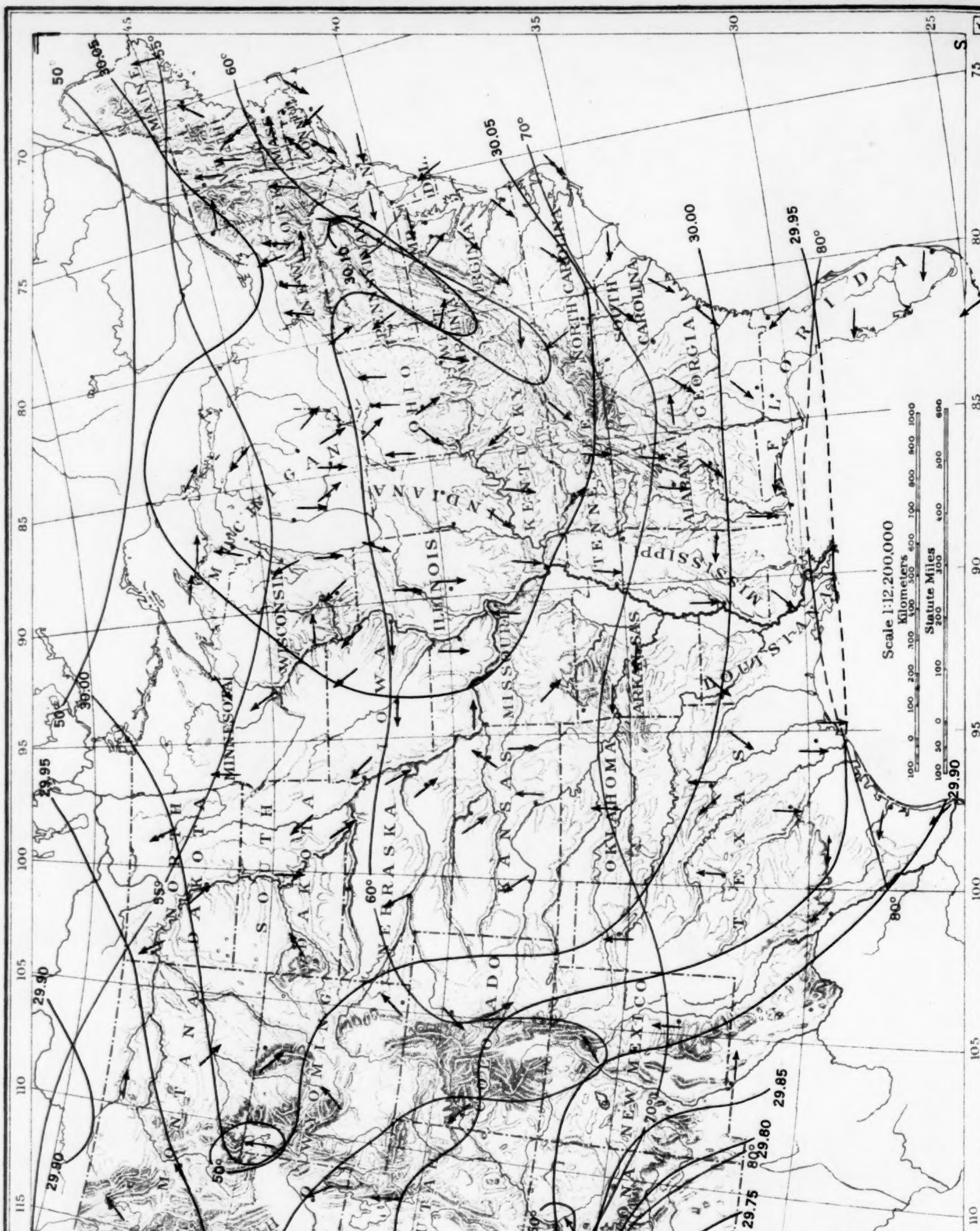

Scale of Shades.
Over 70 per cent.
60 to 70 per cent.
50 to 60 per cent.
40 to 50 per cent.
Under 40 per cent.
Statute Miles
Kilometers

Chart VI. Isobars at Sea level and Isotherms at Surface; Prevailing Winds, September, 1924.



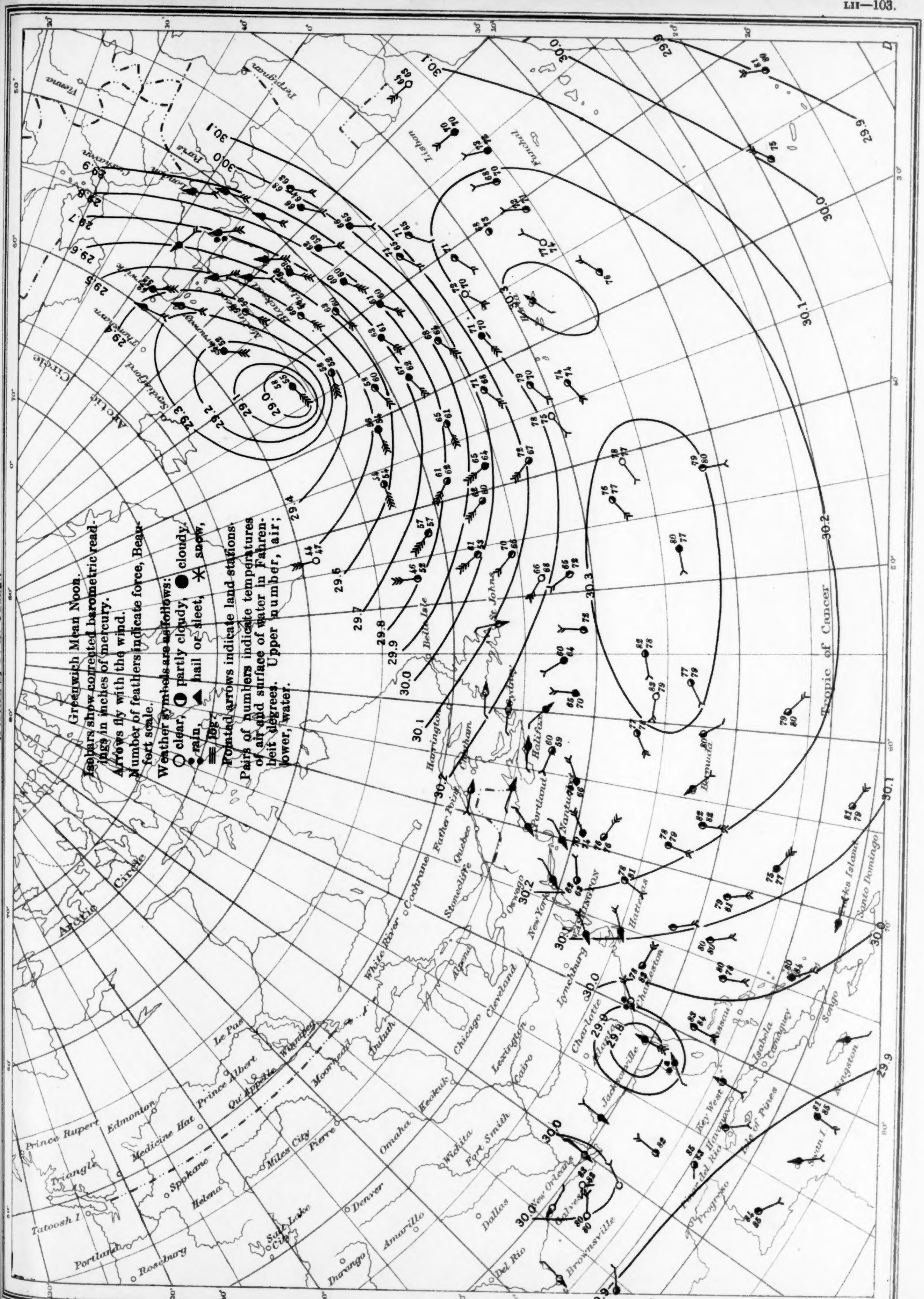

Greenwich Mean Noon.
Isobars show corrected barometric readings in inches of mercury.
Arrows fly with the wind.
Number of feathers indicate force, Beaufort scale.
Weather symbols are as follows: ○ clear, ◐ partly cloudy, ● cloudy, • rain, ▲ hail or sleet, ✱ snow, ≡ fog.
Pointed arrows indicate land stations.
Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.
Tropic of Cancer
Arctic Circle

Chart IX. Weather Map of North Atlantic Ocean, September 17, 1924

(Plotted by F. A. Young.)

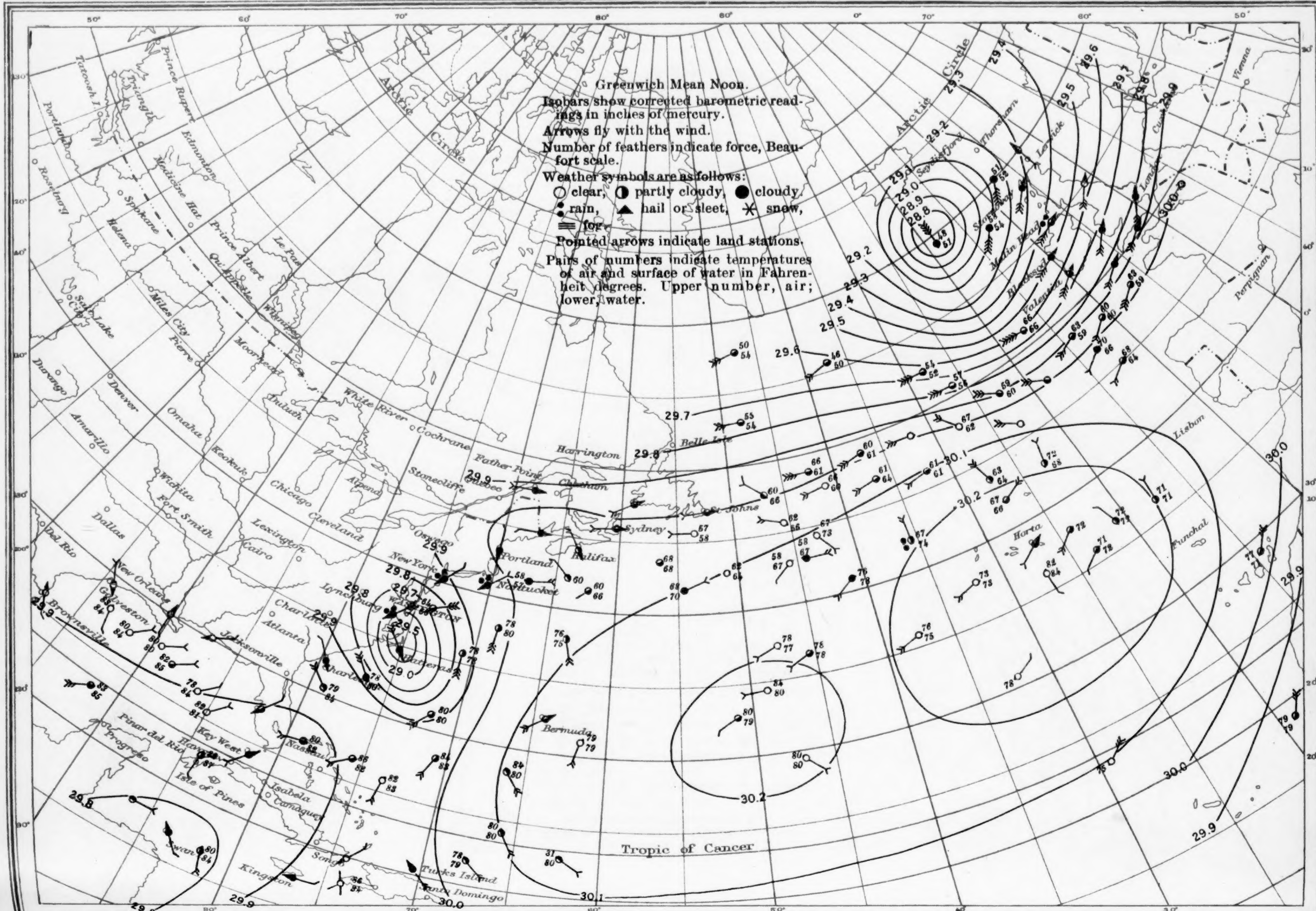


Chart X. Weather Map of North Atlantic Ocean, September 15, 1924
(Plotted by F. A. Young.)

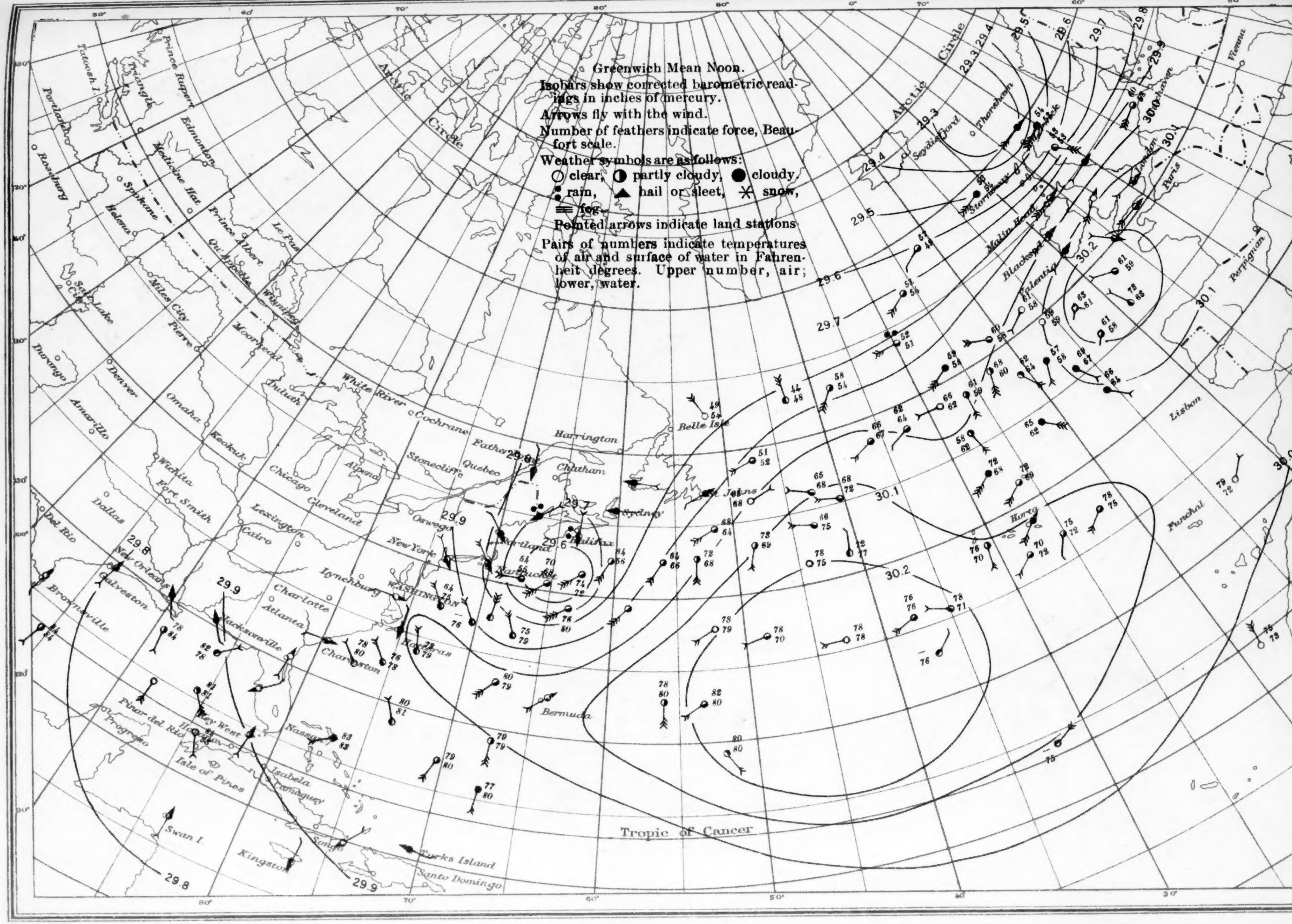


Chart XI. Weather Map of North Atlantic Ocean, September 19, 1924
(Plotted by F. A. Young.)

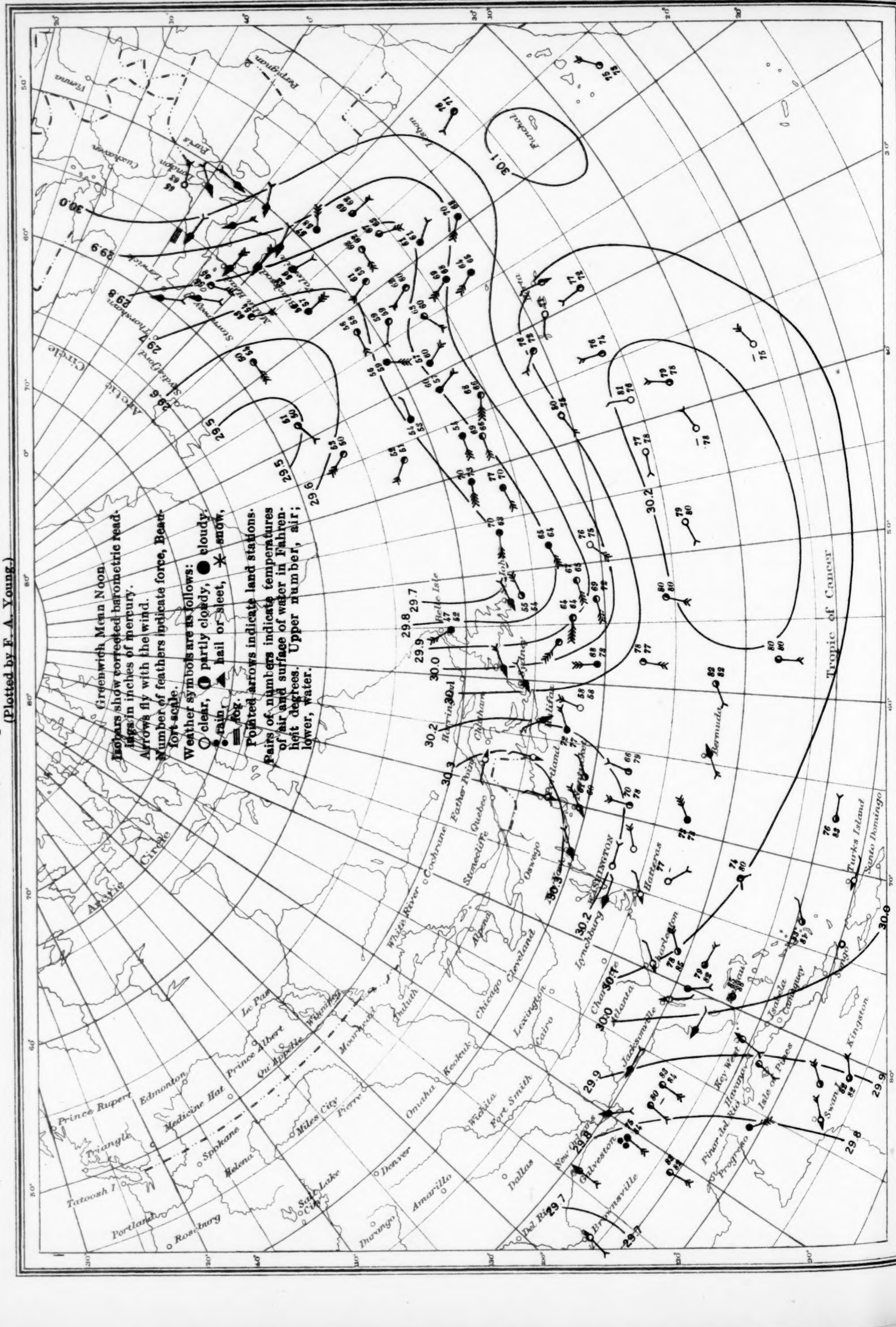


Chart XII. Weather Map of North Atlantic Ocean, September 20, 1924
(Plotted by F. A. Young.)

Chart XII. Weather Map of North Atlantic Ocean, September 20, 1924
(Plotted by F. A. Young.)

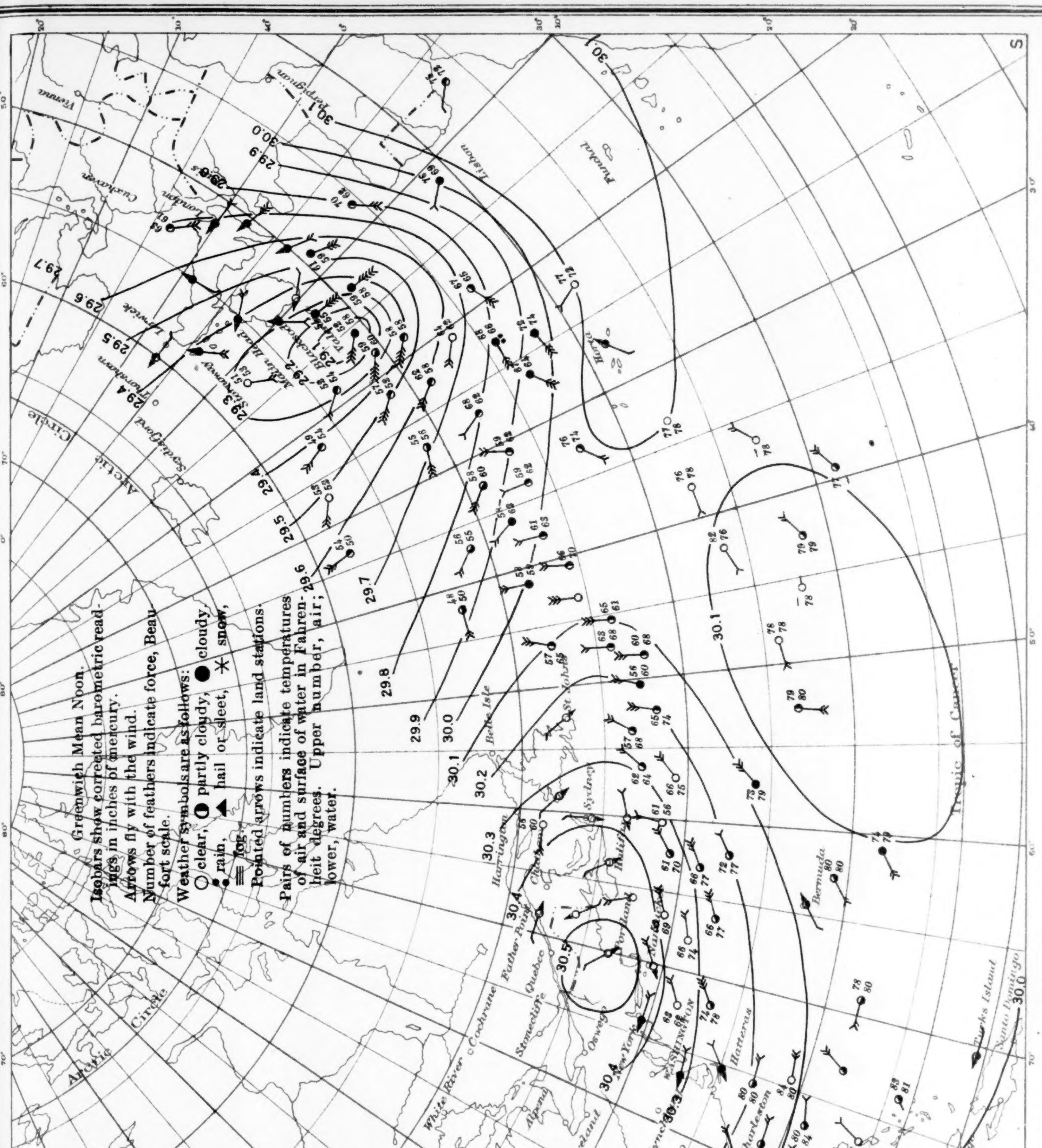


Chart XIII. Weather Map of North Atlantic Ocean, September 21, 1924

(Plotted by F. A. Young.)